PROGRESS REPORT

ENVIRONMENTAL PROGRAMS

— 1977 —

WHITE RIVER SHALE PROJECT

Federal Prototype Oil Shale Leases

Ua and Ub

July 1978

PROGRESS REPORT

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- 1977 -

WHITE RIVER SHALE PROJECT

FEDERAL PROTOTYPE OIL SHALE LEASES U-a AND U-b

July 1978

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Section 1.0

SUMMARY

This "Progress Report -- Environmental Programs" addresses the work accomplished during the period January 1, 1977 - December 31, 1977. The water resources work, however, is reported on a water year basis, which for this report is the period October 1, 1976 - September 30, 1977. During these periods the White River Shale Project continued data collection on water, air and biological resources on and near Federal Oil Shale Prototype Program Lease Tracts Ua and Ub in northeastern Utah.

The "Final Environmental Baseline Report" was published in October 1977. This report summarized the results of the required two year monitoring and data collection program conducted from late 1974 through mid January 1977.

1977 was a dry year on Tracts Ua and Ub. Average precipitation for the water year (October 1976 - September 1977) was 6 inches, only about 60% of normal.

Flow in the White River reflected the low amounts of precipitation received over the region. High flow recorded during 1977 was around 600 cfs, and low flow reached a record low of 13 cfs.

No major differences from baseline period measurements were noted in the air resources monitoring work. Average ozone levels ranged from 50-70 $\mu g/m^3$ over the four seasons of 1977. Peak 24 hour measurements equalled the National Ambient Air Quality Standard (NAAQS) of 160 $\mu g/m^3$ on several occasions. Non-methane hydrocarbons continued to occasionally exceed the NAAQS level by large margins.

The other gases monitored were routinely found in concentrations corresponding to the lower detection limit of the monitoring equipment.

Air borne particulate concentrations were 22 $\mu g/m^3$ as an annual average, and 58 $\mu g/m^3$ as the highest 24 hour average. Both values were below the applicable standards levels of 60 $\mu g/m^3$ and 150 $\mu g/m^3$ respectively.

The dry year severely reduced vegetation growth and subsequently reduced the populations of most of the various animal species.

Work on revegetating processed shale continued on schedule during 1977. The dry weather conditions caused problems with the field experiments. But good progress was made regarding developing techniques for using native plant species for revegetation purposes.

Plans for 1978 call for continuing the level and scope of work performed during 1977.

Section 2.0

INTRODUCTION

The White River Shale Project (WRSP) was formed in 1974 to carry out the joint development of the two Federal Prototype Oil Shale Lease Tracts (Ua/Ub) in Utah. WRSP is responsible to Sunoco Energy Development Company, Sohio Natural Resources Company and Phillips Petroleum Company for completing the planning and implementation of development activites.

Two significant tasks have been completed by WRSP since work under the leases began. First, the Detailed Development Plan required by the leases was submitted to the U. S. Geological Survey - Area Oil Shale Supervisor (AOSS) in June of 1976. This plan describes the activities, timing and results expected for development of Tract Ua/Ub into a 100,000 barrel per day oil shale processing facility. Second, the required two-year Environmental Baseline Program was completed in January of 1977, and the final report for this work was published in October of 1977.

Operations under the Ua/Ub leases, however, were suspended for one year effective November 1, 1976. This effectively postponed the implementation of the program described in the Detailed Development Plan. The lease terms were suspended because the Environmental Baseline Program detected levels of airborne ozone and non-methane hydrocarbons which exceeded Federal National Ambient Air Quality Standards. This situation precludes proceeding with development as described in the Detailed Development Plan until the regulations are modified or provisions are made that allow construction and operations of facilities in areas which do not meet air quality standards under natural conditions.

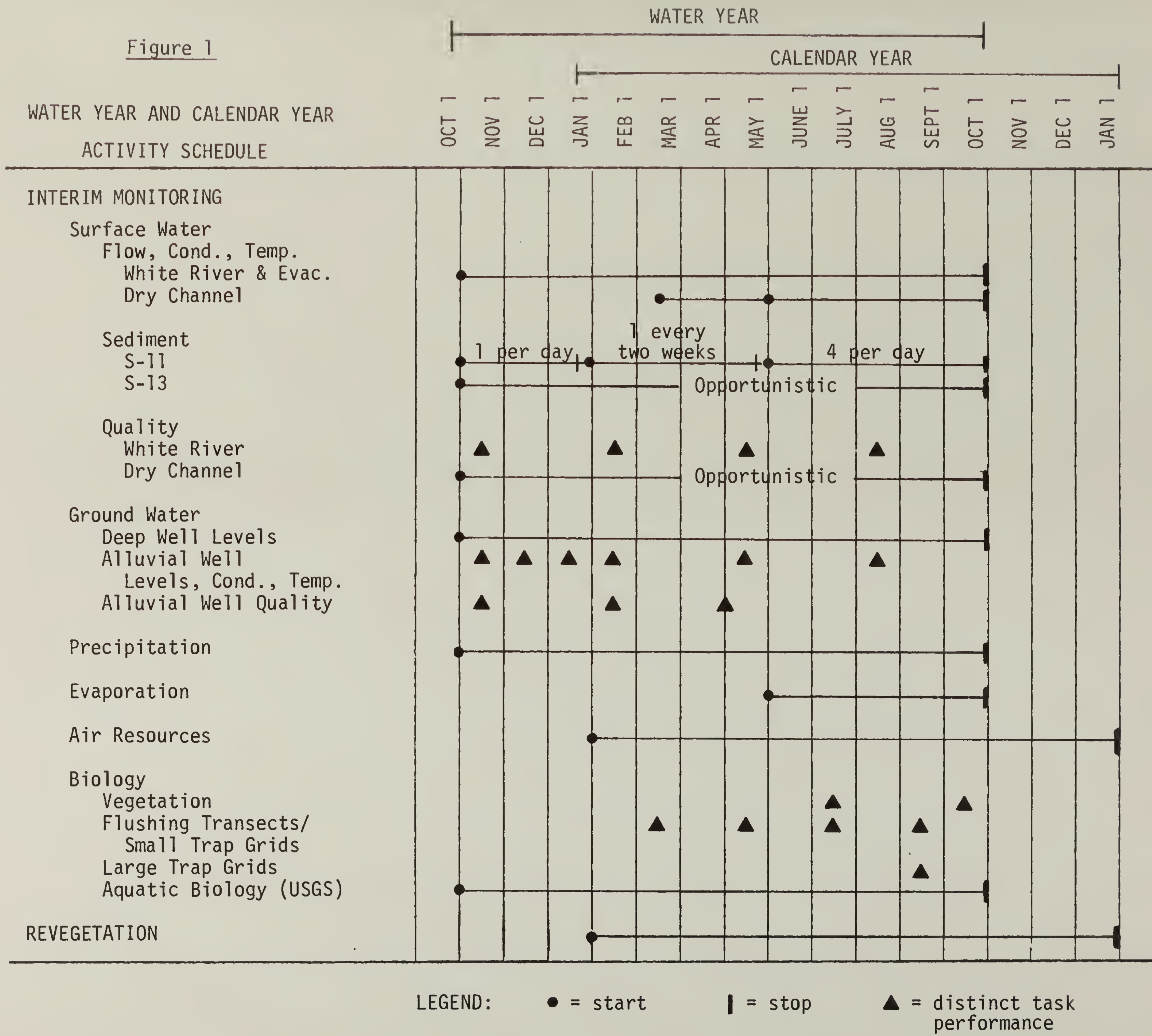
In December of 1976 the "Work Plan -- Lease Suspension Period Environmental Programs" was submitted to the Area Oil Shale Supervisor (AOSS). This plan presented a program for activities to be carried out during the suspension period. It covered the plans for: 1) completing and reporting the results of the two-year Baseline Program, 2) conducting an Interim Environmental Monitoring Program (subsequently approved by AOSS), 3) continued revegetation research, and 4) reporting on the progress and results of the environmental programs. The "Work Plan" forms the framework for environmental work done during 1977, as well as for future years.

WRSP is also, however, prevented from going forward with development activities by questions concerning title to the Ua and Ub property. These questions led the Utah Federal District Court to grant a preliminary injunction to WRSP against the Department of Interior concerning the stipulations of the leases on June 8, 1977. The order of preliminary injunction was signed July 1, 1977 and was made effective May 31, 1977.

WRSP, however, plans to continue environmental monitoring work at a level similar to that carried out during 1977.

This "Progress Report -- Environmental Programs" reports on activities carried out during the 1977 calendar year and the 1977 water year (see Figure 1). WRSP plans to issue a progress report annually. The next report, therefore, will cover 1978 and be published by mid-year 1979.

Figure 1


WATER YEAR
CALENDAR YEAR
WATER YEAR AND CALENDAR YEAR
ACTIVITY SCHEDULE
OCT 1
NOV 1
DEC 1
JAN 1
FEB 1
MAR 1
APR 1
MAY 1
JUNE 1
JULY 1
AUG 1
SEPT 1
OCT 1
NOV 1
DEC 1
JAN 1
INTERIM MONITORING
Surface Water
Flow, Cond., Temp.
White River & Evac.
Dry Channel
Sediment
S-11
S-13
1 per day
1 every two weeks
4 per day
Opportunistic
Quality
White River
Dry Channel
Opportunistic
Ground Water
Deep Well Levels
Alluvial Well
Levels, Cond., Temp.
Alluvial Well Quality
Precipitation
Evaporation
Air Resources
Biology
Vegetation
Flushing Transects/
Small Trap Grids
Large Trap Grids
Aquatic Biology (USGS)
REVEGETATION
LEGEND:
● = start
❙ = stop
▲ = distinct task performance

Section 3.0

BASELINE ENVIRONMENTAL MONITORING PROGRAM

The field work for the required two-year Environmental Baseline Monitoring Program was completed January 15, 1977.

The "Final Environmental Baseline Report" was published in October of 1977.

Section 4.0

INTERIM ENVIRONMENTAL MONITORING PROGRAM PROGRESS

The two-year Environmental Baseline Program was completed in total in January 1977. This section will discuss the Interim Monitoring Program which was implemented after completion of the Baseline Program under the terms of the "Notice of Suspension of Operations under the Lease Terms."

The Interim Monitoring Program's primary purpose is to ensure the continuity of data gathering so as to maintain the applicability of the two-year Baseline survey to future monitoring periods. The program discussed in this section, therefore, was planned to fill the "interim" period between completion of the Baseline survey work and the implementation of the monitoring program to be conducted during oil shale development activities.

An additional purpose of the Interim Monitoring Program is to develop more data in areas of specific concern. One of these areas, for example, deals with the levels of the air quality parameters ozone and non-methane hydrocarbons. Levels of these materials were found to exceed National Ambient Air Quality Standards during Baseline monitoring.

Three aspects of the environment are being monitored during the suspension period. These are air, water and biological resources. Figure 1 summarizes the schedule of monitoring activities.

The following sections discuss the work done during the period October 1, 1976 - September 30, 1977 for water resources, and January 1, 1977 - December 31, 1977 for air and biological resources.

4.1 WATER RESOURCES

The two year water resources Environmental Baseline Monitoring Program was completed October 1, 1976. An "interim" monitoring program was approved by the AOSS in November. This program was in operation until the program presented in the December 1976 Work Plan was approved for the lease suspension period.

This section of the Progress Report will discuss the monitoring work performed in the period November 1, 1976 - October 1, 1977.

The United States Geological Survey (USGS) is conducting a water resources data collection program in the drainage area of the Uintah Basin. Much of this data collection is taking place in the immediate vicinity of Tract Ua/Ub. The WRSP Water Resources Interim Monitoring Program was designed to be used in conjunction with pertinent portions of the proposed USGS program. The two data collection programs combined adequately monitor streamflow, suspended sediment, and water quality at locations on the White River, Evacuation Creek and at the mouths of Southam Canyon, Asphalt Wash and Hell's Hole Canyon. At this time, some data from USGS surface water stations are not available. Therefore, a supplemental report covering the 1977 water year will be published when this data become available.

Alluvial aquifers are monitored for water levels and quality at locations upstream and downstream of the tract on the White River and on Evacuation Creek and at locations at the mouths of Southam Canyon, Asphalt Wash, and Hell's Hole Canyon. Precipitation and evaportation are monitored at the proposed plant site, in Southam Canyon, and the surrounding area.

The Bird's Nest and Douglas Creek bedrock aquifers are continuously monitored for water level fluctuations. Additional semiannual water level measurements are being taken for area correlation.

Figure 2 shows the locations of sites for the four types of monitoring being conducted -- surface water, deep aquifer water, alluvial water and precipitation/evaporation monitoring. All supporting data are shown in the figures and tables of the text and in the field data section. All USGS data in this report are preliminary and subject to revision.

VTN COLORADO, Inc. is under contract to WRSP for the conducting of the water resources monitoring program.

4.1.1 Surface Water

The surface water monitoring program comprises work efforts of both the USGS Water Resources Division and WRSP. The division of responsibilities is shown in Table 1. In the past more than one system of nomenclature has been used for surface water stations. This report will use only the USGS system of nomenclature for station numbers and names. A comparison of nomenclature for surface water stations is shown in Table 2.

4.1.1.1 Objectives. The objectives of the surface water monitoring program are to ensure the applicability of the two-year Baseline data to future monitoring periods and to correlate data collected from the two-year Baseline White River sites with data from the recently installed USGS station (09306395) upstream of Tract Ua/Ub.

4.1.1.2 Methods. Data collection methods during the reporting period were concerned with streamflow, sediment and water quality data.

FIGURE 2

WATER RESOURCES
MONITORING SITES

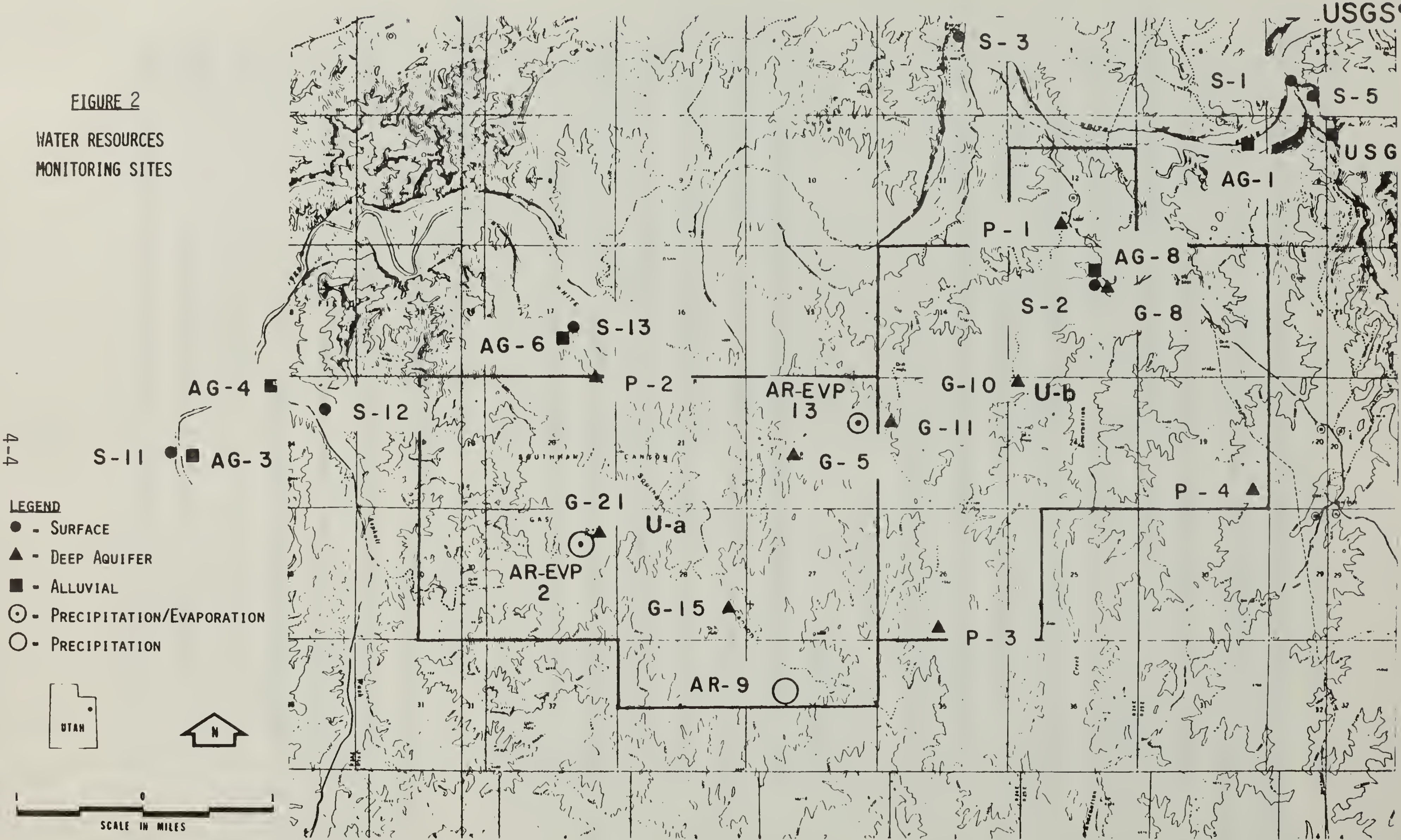


TABLE 1

RESPONSIBILITY FOR SURFACE WATER MONITORING

Activity	Responsibility
Flow	
09306700 continuous	VTN
09306400 30-day high-flow and low-flow for Stateline correlation	VTN
09306610 February-October	VTN
09306395	USGS
09306500	USGS
09306430	USGS
09306405 and 09306625	USGS
Suspended Sediment	
09306700 continuous (high-flow, 4 samples daily, February-October, and 1 sample daily November-January)	VTN
09306610 opportunistic	VTN
09306430 and 09306395 auto samplers - monthly	USGS
09306405 and 09306625 2-bottle single stage - opportunistic	USGS
Water Quality	
09306700 quarterly January, April, July, October	VTN
09306610 opportunistic	VTN
09306700 and 09306610 continuous SC and Temperature	VTN
09306400 Temperature and SC for 1 month low and 1 month high for $\geq$0.9 Correl. Coeff.	VTN
09306395, 09306430, and 09306500 quarterly samples	USGS

TABLE 2

COMPARISON OF NOMENCLATURE FOR
SURFACE WATER STATIONS

Designation 1	Designation 2 (USGS)	Name (USGS)
	09306395	White River Near Colorado State Line, Utah
S-1	09306400	White River Above Hell's Hole Canyon, Near Watson, Utah
S-5	09306405	Hell's Hole Canyon at Mouth, Near Watson, Utah
	09306410	Evacuation Creek Above Missouri Creek, Near Watson, Utah
S-6	09306420	Evacuation Creek at Watson, Utah
S-2	09306430	Evacuation Creek Near Mouth, Near Watson, Utah
S-3	09306500	White River Near Watson, Utah
S-13	09306610	Southam Canyon Wash at Mouth, Near Watson, Utah
S-12	09306625	Asphalt Wash at Mouth, Near Watson, Utah
S-11	09306700	White River Below Asphalt Wash, Near Watson, Utah

Streamflow was measured continuously by the WRSP on the White River downstream from the tract (09306700). The gaging station visitation and maintenance program were sufficient to ensure as near continuous stream-stage measurement throughout the lease suspension period as practical. The station was calibrated using current meter measurements as frequently as called for by good hydrological practices, but no less frequently than once per month.

Streamflow was monitored at an existing station, 09306400, on the White River above the tract during low (1976) and high flow in order to provide information for verifying correlation between 09306400 and the new USGS upstream White River station, 09306395. The digital recorder tapes were removed and processed monthly.

Streamflow was also measured by WRSP in lower Southam Canyon (09306610). According to plan, this station was started up on February 17, 1977, after the winter shutdown. It was operated through October. The station was visited during the period of operation at least once each month. The digital recorder tapes were removed and processed once a month.

Streamflow was monitored continuously by the USGS at a new station, 09306395, located 1 mile upstream from 09306400 on the White River, at 09306500 on the White River near Watson, at 09306430 on Evacuation Creek near the mouth, and at 09306420 on Evacuation Creek at Watson. Stations 09306625 on Asphalt Wash near the mouth and 09306405 in Hell's Hole Canyon near the mouth were put into operation on February 10, 1977, and February 7, 1977, respectively after the winter shutdown.

Suspended sediments were measured by the WRSP at 09306700 and 09306610. At 09306700 the automatic suspended sediment sampler was to be operated continuously according to the Work Plan. Severe icing conditions,

however, required that it be shut down from December 18, 1976, to March 31, 1977. During the shutdown manual samples were withdrawn once every two weeks. The automatic sediment sampler was restarted on March 31, 1977, and set to collect four samples a day beginning April 11, 1977, continuing through October 31, 1977. The duration of this sampling period past October will depend upon the prevailing hydrological conditions and the judgment of the resident senior WRSP hydrographer. Manual ETR suspended sediment measurements were perfromed at intervals necessary to ensure calibration of the automatic sampler, but a least monthly through the year. Because of the lack of major snowmelt runoff, no sampling beyond the normal schedule was done.

No suspended sediment samples were collected at 09306610. A single-stage sampler and a crest gauge were maintained at that location to enhance the chances for data collection.

Sediment samples were analyzed by the WRSP, and daily values of streamflow and suspended sediment were calculated.

An automatic sediment sampler was used by the USGS at 09306395 and 09306430, and two-bottle single-stage samplers were in use at the 09306405 and 09306625 locations.

Water quality samples were collected by WRSP at 09306700. Samples at 09306700 were collected October 21, 1976, January 4, 1977, April 27, 1977, July 20, 1977, and October 11, 1977. No water quality samples were collected at 09306610. Dissolved oxygen, temperature, pH and conductivity were measured in the field at the time samples were collected. The constituents were analyzed in accordance with the quarterly and semiannual analytical schedule shown in Table 3.

TABLE 3

OIL SHALE PROJECT - WATER QUALITY

SURFACE WATER SCHEDULE - USGS (REVISED DECEMBER 3, 1975)

Samples will be collected and analyzed according to the following schedule:

<u>Quarterly</u> (October, January, April, July)

Calcium	Floride	Nitrate
Magnesium	Silica	Nitrite
Sodium	Iron	Ammonia
Potassium	Aluminum	Total Kjeldahl Nitrogen
Chloride	Boron	Chemical Oxygen Demand
Sulfate	Lithium	Chlorophyll A
Bicarbonate	Strontium	Chlorophyll B
Carbonate	Magnese	Color
Alkalinity	Phosphate	Turbidity
Hardness	Total Phosphorus	Dissolved Solids

<u>Semiannually</u> (October, April)

Arsenic	Selenium	Lead
Cadmium	Vanadium	*Detergents
Chromium	Zinc	Organic Carbon (Dissolved)
Copper	Barium	*Pesticides
Mercury	Sulfide	Phenols
Molybdenum	Bromide	**Gross Alpha and Beta

Whenever a station is visisted, field measurements will be made of pH, temperature, conductivity and dissolved oxygen.

* Not included in WRSP Program.

** If gross alpha activity is measured at greater than 4 picocuries/liter, then analysis for radium 226 and for natural uranium will be done. If gross beta activity is greater than 100 picocuries/liter, then analysis for Sr^{90} and Ce^{137} will be done.

Temperature and conductivity were measured continuously at 09306700. Both probes were checked and calibrated regularly, and the digital recorder tapes were pulled and processed monthly. Temperature and conductivity probes were maintained at 09306610 during the period of its operation.

At 09306400, streamflow, temperature and conductivity were monitored continuously from October 1, 1976, to November 26, 1976, to verify correlation with 09306395. Another period of concurrent operation began April 25, 1977, continuing to June 9, 1977. This period corresponded to the high flow period in 1977. Correlation coefficients for streamflow have been calculated. Correlation coefficients will be caluculated between 09306395 and 09306400 temperature and conductivity records within 30 days following receipt of final USGS data for 09306500 and 09306395. Operation of 09306400 will be permanently discontinued if the correlation coefficient between the 09306400 and 09306395 records from both periods is ≥0.9, and if the standard error of estimate is ≤10% based on daily values. If this criteria is not met, then the 09306500 records will be used to determine whether the records contain erroneous data which may bias the analysis.

Water quality samples were collected by the USGS and analyzed quarterly at 09306430, 09306500, and 09306395. The samples were analyzed for the constituents listed in Table 3.

4.1.1.3 Results to date:

Streamflow: White River

During the study period, peak streamflow in the White River was considerably less than during the Baseline period (for example, maximum discharge at 09306500 was 17.05 m^3,sec (602 cfs) on June 3, 1977). Also,

baseflow reached an extremely low value compared to the Baseline period (for example, minimum discharge at 09306500 was 0.37 m^3/sec (13 cfs) on July 3, 1977). In general, streamflow during the 1977 water year was well below normal because of much less snowpack than normal in the mountains and therefore less runoff. Baseflow occurred from October 1976 through early January 1977 and resumed earlier than expected in late June 1977. Runoff from the lower basin began in mid January 1977. Runoff from the upper basin began in mid April and lasted until mid June 1977. (See Figures 3 through 6 and Table 4.) At station 09306700 temperature followed the annual sinusoidal pattern, and specific conductance followed the inverse relationship to streamflow established during the Baseline study (see Figures 4 and 6 and Table 4). Temperature and specific conductance records are not available for stations 09306500 and 09306395 at this time.

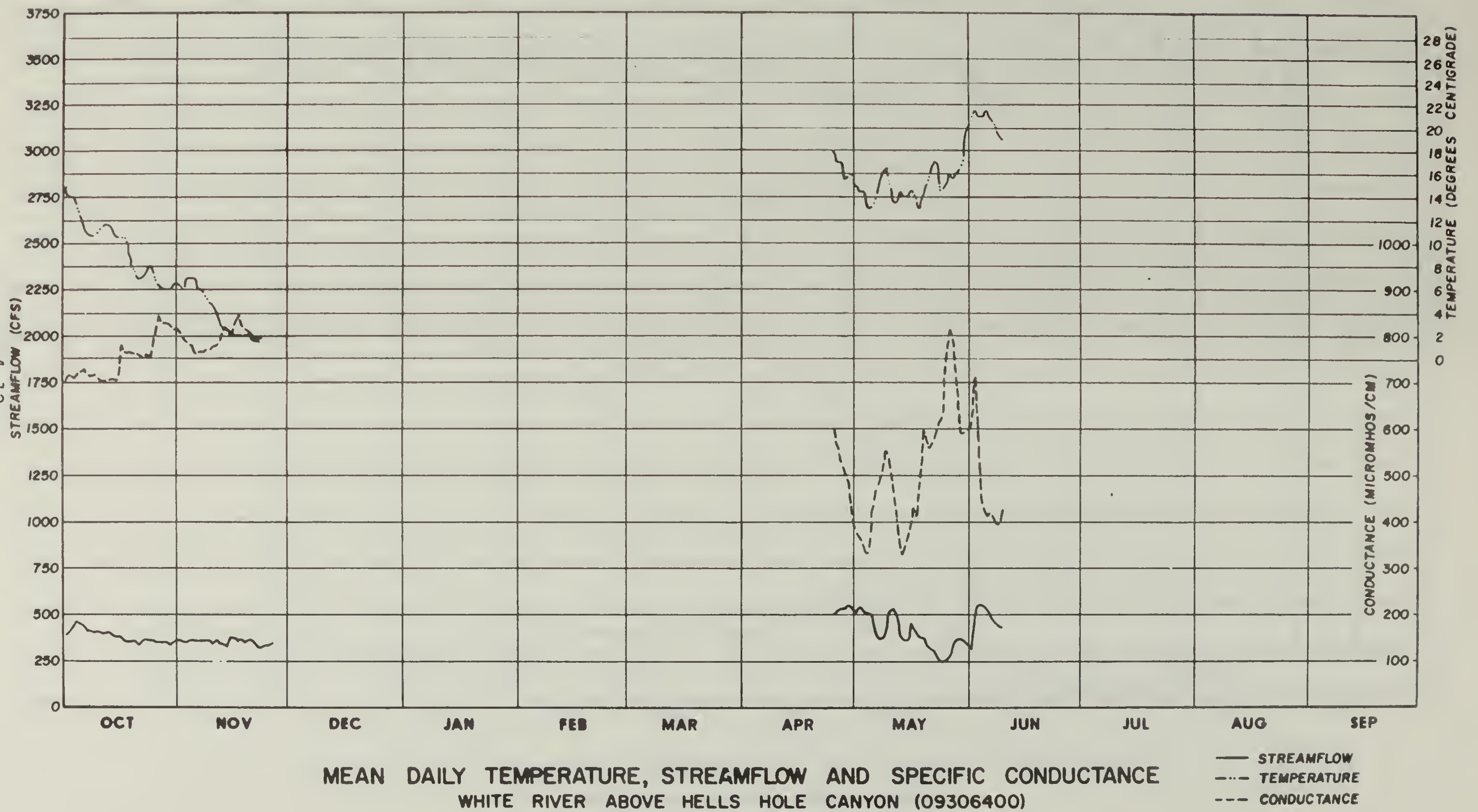
The results of the correlation of streamflow measurements at stations 09306395 and 09306400 are shown in Table 5. The data meet the criteria set in the work plan for the Interim period (that the correlation coefficient from both time periods if $\geq$0.9 and the standard error of estimate is $\leq$10% based on daily values). The correlation was made by simple linear regression. Data for correlations of temperature and specific conductance measurements are not available at this time.

Streamflow: Evacuation Creek

Streamflow, temperature, and specific conductance records are not available from the USGS for stations 09306410, 09306420, and 09306430 at this time.

MEAN DAILY STREAMFLOW
WHITE RIVER NEAR COLORADO STATE LINE (09306395)
OCTOBER 1976 - SEPTEMBER 1977

FIGURE 3



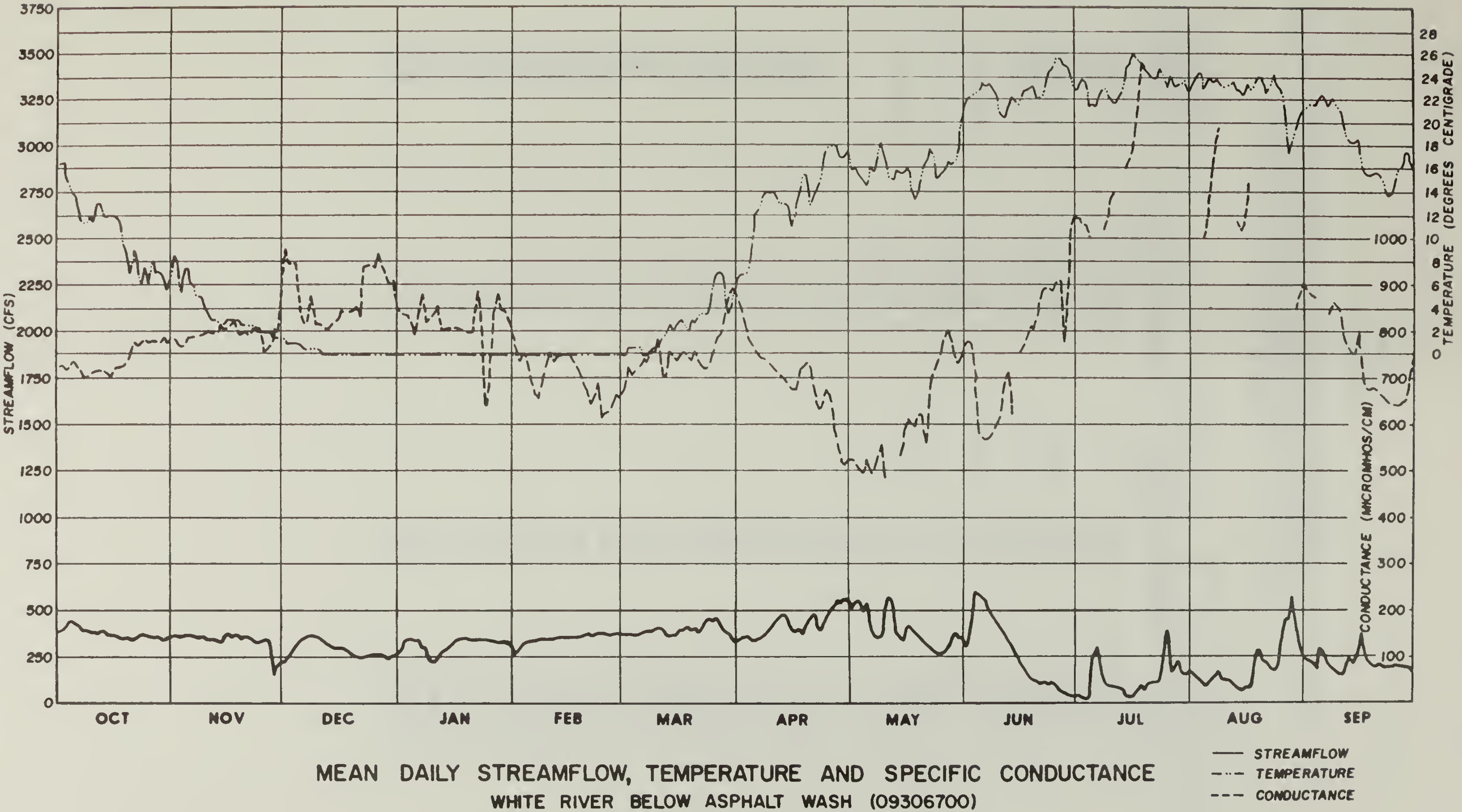
MEAN DAILY TEMPERATURE, STREAMFLOW AND SPECIFIC CONDUCTANCE
WHITE RIVER ABOVE HELLS HOLE CANYON (09306400)
OCTOBER 1976 - SEPTEMBER 1977

FIGURE 4

MEAN DAILY STREAMFLOW
WHITE RIVER NEAR WATSON (09306500)
OCTOBER 1976 - SEPTEMBER 1977

VTN

FIGURE 5



MEAN DAILY STREAMFLOW, TEMPERATURE AND SPECIFIC CONDUCTANCE
WHITE RIVER BELOW ASPHALT WASH (09306700)
OCTOBER 1976 - SEPTEMBER 1977

vtn

FIGURE 6

TABLE 4

MEAN DAILY STREAMFLOW, TEMPERATURE, AND SPECIFIC CONDUCTANCE
WHITE RIVER BELOW ASPHALT WASH (09306700)
OCTOBER 1977

Date	Streamflow (cfs)	Temperature (°C)	Specific Conductance (μmhos)
10/1/77	170	12.8	760
10/2/77	155	13.2	755
10/3/77	165	14.4	762
10/4/77	162	14.9	778
10/5/77	160	16.2	770
10/6/77	158	15.8	
10/7/77	235	14.3	
10/8/77	340	12.4	
10/9/77	305	12.1	
10/10/77	280	11.0	
10/11/77	252	10.5	
10/12/77	252	10.3	
10/13/77	256	10.2	821
10/14/77	263	11.0	830
10/15/77	295	11.4	840
10/16/77	284	11.8	815
10/17/77	298	12.0	802
10/18/77	290	11.8	797
10/19/77	290	11.6	771
10/20/77	290	11.8	765
10/21/77	290	12.4	760
10/22/77	290	11.9	755
10/23/77	290	11.3	787
10/24/77	290	10.5	749
10/25/77	290	10.0	742
10/26/77	290	10.3	729
10/27/77	290	10.3	732
10/28/77	291	10.6	775
10/29/77	291	10.6	837
10/30/77	298	10.4	840
10/31/77	294	9.4	911

TABLE 5

CORRELATION OF STREAMFLOW MEASUREMENTS
BETWEEN STATIONS 09306395 AND 09306400

Independent Variable (X)	Dependent Variable (Y)	Time Period	Correlation Coefficient	Standard Deviation of Y Residuals Divided by Mean of Y Values (in %)
09306400	09306395	10/1/76 to 11/26/76	0.978	1.32
09306400	09306395	4/25/77 to 6/9/77	0.986	3.96
09306395	09306400	10/1/76 to 11/26/76	0.978	1.75
09306395	09306400	4/25/77 to 6/9/77	0.986	3.69

Streamflow: Dry Washes

In Southam Canyon (station 09306610) there were five flow events from October 1976 through October 1977. They are shown in Table 6. Cross sections of the channel were taken on August 9 and 19 and discharges were calculated. Because the channel cross section changes during each flow event, discharges cannot be estimated accurately for the other three flow events. Apparently, the greatest discharge at this station was the result of the most intense precipitation during the time period. This supports the conclusion in the Baseline study that intensity is the key factor involved with runoff. Continuous specific conductance measurements during flow events are shown in Table 7. No data for continuous temperature measurements during flow events are available. The hourly measurements do not represent the specific conductance during streamflow. It is more likely that they represent the specific conductance of runoff standing in the stilling well after flow has occurred. It is probable that the maximum readings on the first day of the flow event represent specific conductance during streamflow.

Data for streamflow, temperature, and specific conductance at stations 09306405 and 09306625 are not available at this time.

TABLE 6

FLOW EVENTS

SOUTHAM CANYON WASH AT MOUTH (09306610)
OCTOBER 1976 - OCTOBER 1977

DATE OCCURRED	DATE MEASURED	HIGH WATER MARK (FT)	MAXIMUM INSTANTANEOUS DISCHARGE (CFS)
July 4-5, 1977	July 5, 1977	0.58	--
July 29-30, 1977	August 9, 1977	0.63	5.4
August 17-18, 1977	August 19, 1977	1.14	26.3
August 25-26, 1977	August 26, 1977	0.71	--
October 6-7, 1977	October 7, 1977	0.74	--

TABLE 7

SPECIFIC CONDUCTANCE MEASUREMENTS DURING FLOW EVENTS

SOUTHAM CANYON WASH AT MOUTH (09306610)
OCTOBER 1976 - OCTOBER 1977

DATE	TIME	SPECIFIC CONDUCTANCE (μmhos)	REMARKS
July 4, 1977	1800	163	Maximum=216
	2400	207	
July 5, 1977	0600	220	Maximum=222
	1200	206	
July 29, 1977	2400	119	Maximum=134
July 30, 1977	0600	163	Maximum=180
	1200	50	
August 17, 1977	2400	365	Maximum=426
August 18, 1977	0600	430	Maximum=466,
	1200	441	Mean Daily=439
	1800	453	
	2400	433	
August 19, 1977	0600	235	Maximum=294
	1200	141	
August 25, 1977	0600	309	Maximum=510
	1200	346	
	1800	348	
	2400	354	
August 26, 1977	0600	369	Maximum=376
	1200	371	
October 6, 1977	2400	238	Maximum=276
October 7, 1977	0600	227	Maximum=358
	1200	250	

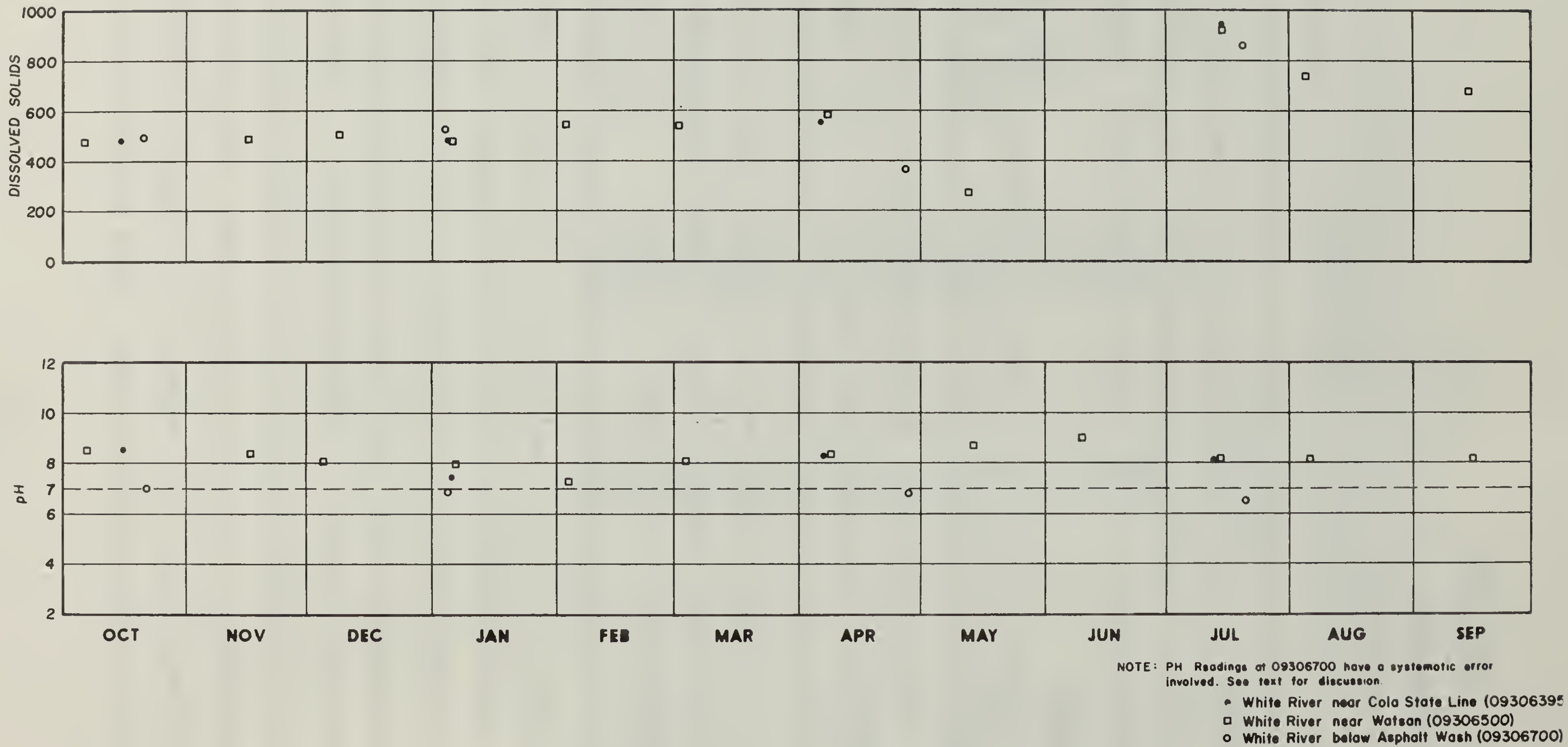
Water Quality: White River

General Characteristics

1) Dissolved Solids: Levels of concentration followed the inverse relationship to streamflow that was established during the Baseline study. However, the maximum measurement during the year was higher than any measurement during the Baseline study (908 mg/l vs. 717 mg/l), and it occurred in July when streamflow reached a much lower level than in the prior two years. There was little variation between stations. Data are shown in Figure 7.

2) Suspended Sediment: Data at station 09306700 indicate that the annual maximum occurred immediately after extremely low streamflow during a period of rapidly rising stage. The maximum concentration was higher than any measurement during the Baseline study (47,600 mg/l vs. 37,600 mg/l). In general, the level of concentration continued to follow the direct relationship to streamflow established in the Baseline study. Data for this station are shown in Figure 8 and Table 8. Data from stations 093006395 and 09306500 are not available at this time.

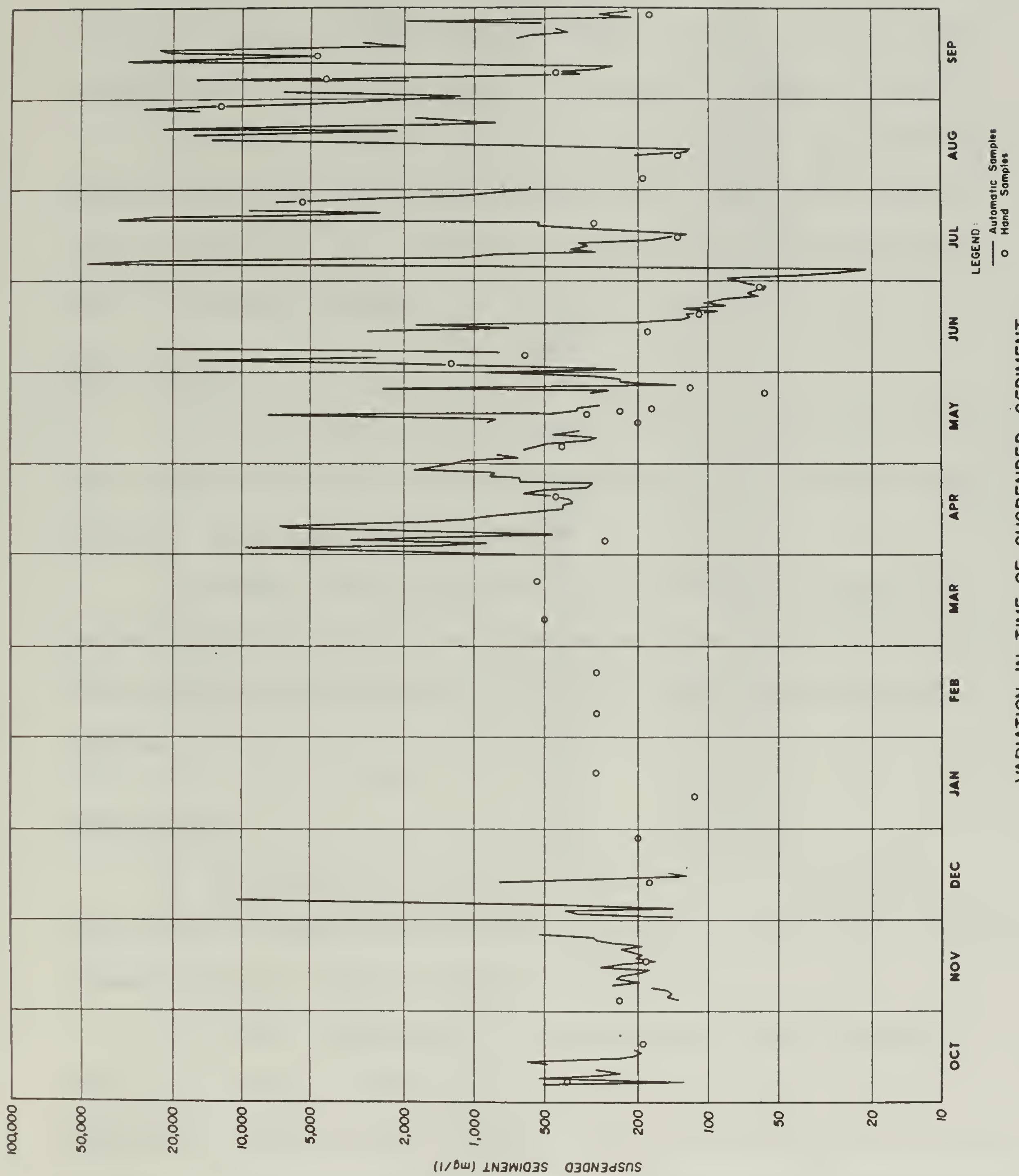
3) pH: At stations 09306390 and 09306500 ph levels continued to be slightly above 8.0 during the entire year as in the Baseline study. However, at station 09306700 the pH level remained between 6.5 and 7.0 (compared to slightly above 8.0 during the Baseline study) throughout the year. An investigation of this data indicated that pH papers were being used at 09306700 and a pH meter at 09306395 and 09306500. A comparison of the paper and the meter on January 30, 1978 at 09306700 showed that the paper had readings 1.5 units lower than the meter. This approximate correction for the systematic error would make the readings at 09306700 similar to those from the stations upstream. These data are shown in Figure 7.



VARIATION OF GENERAL CHARACTERISTICS
WHITE RIVER FROM ABOVE HELLS HOLE CANYON TO BELOW ASPHALT WASH
OCTOBER 1976 - SEPTEMBER 1977

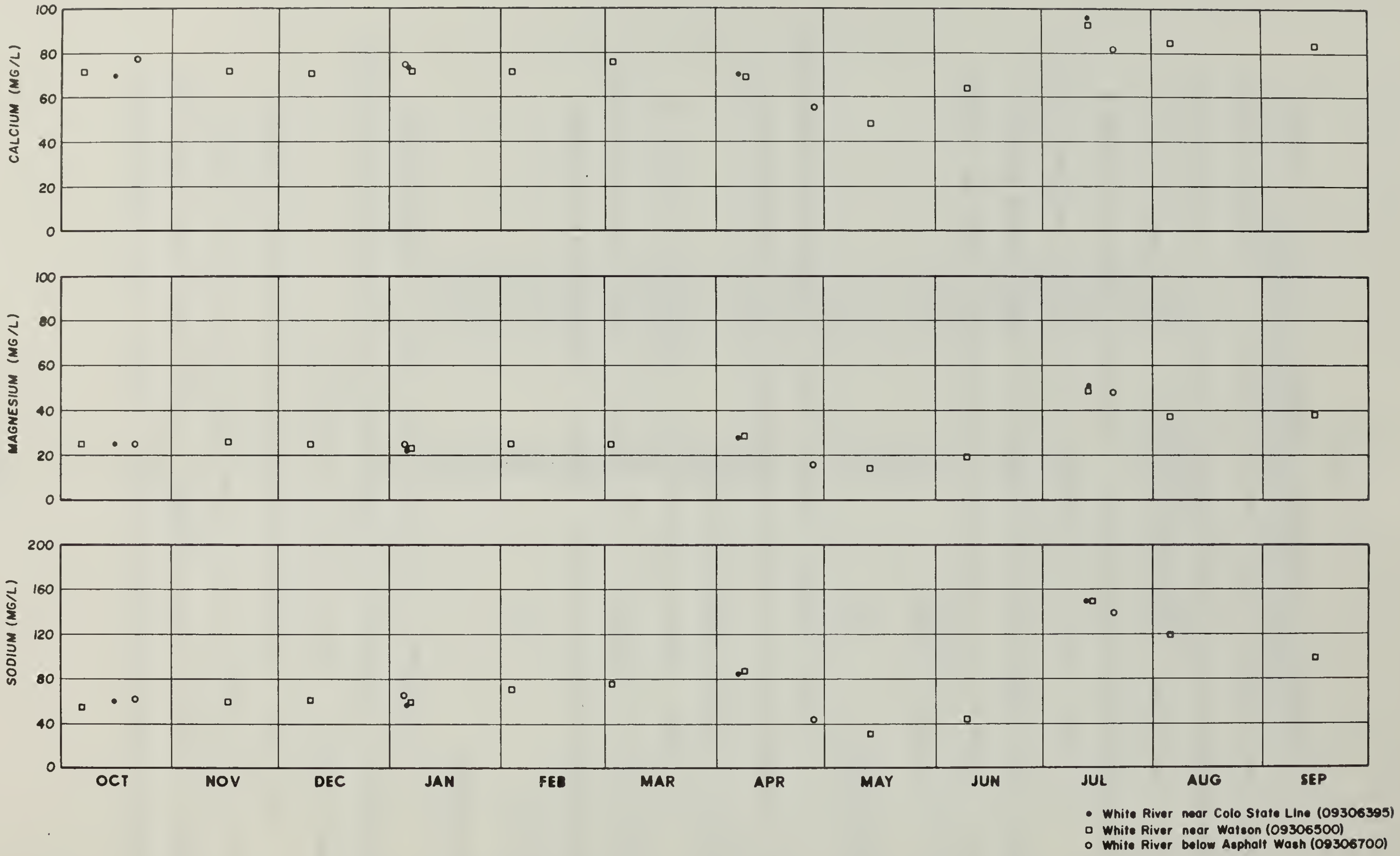
vtn

FIGURE 7



VARIATION IN TIME OF SUSPENDED SEDIMENT
AT WHITE RIVER BELOW ASPHALT WASH (09306700)
OCTOBER 1976 - SEPTEMBER 1977

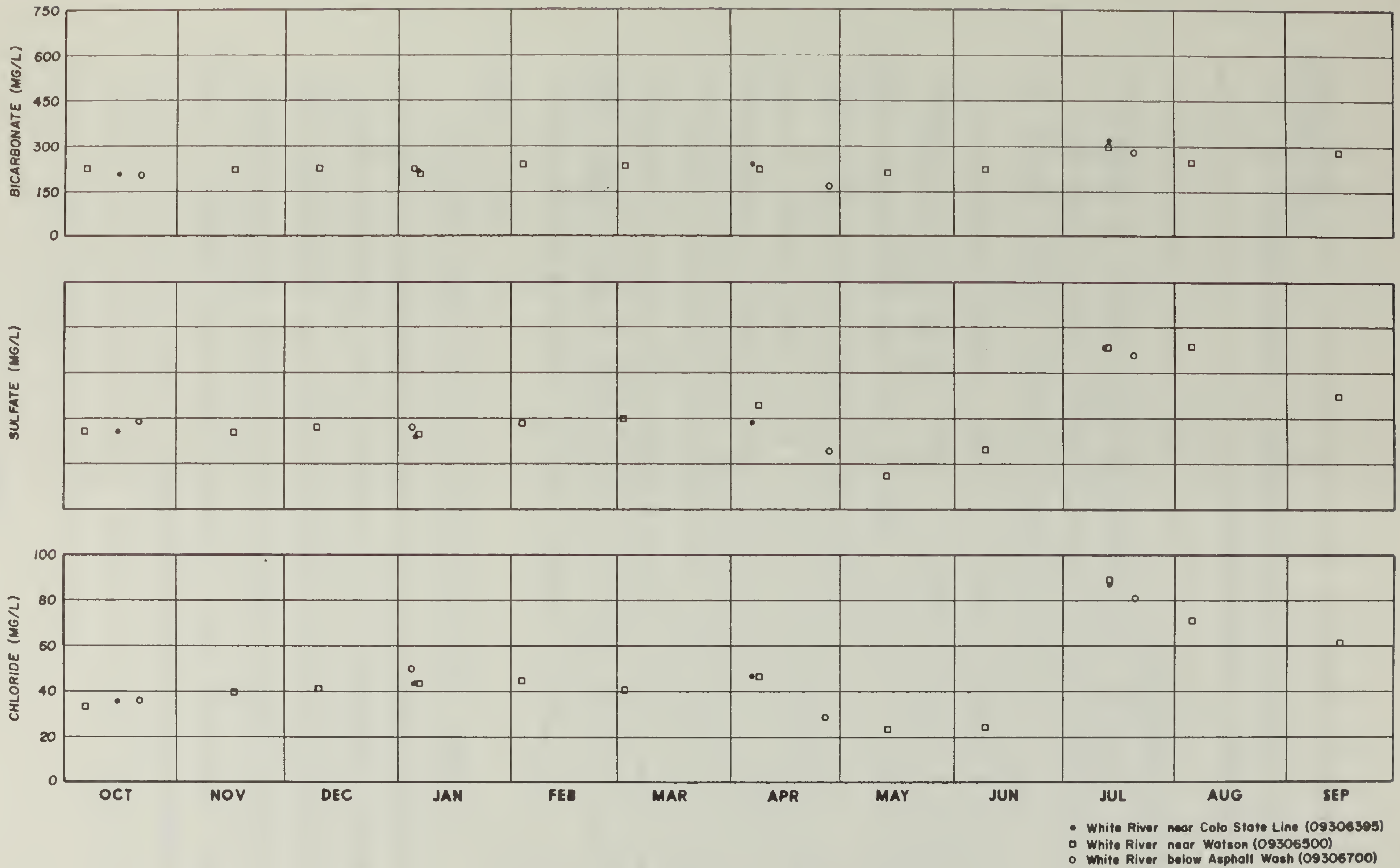
FIGURE 8



VARIATION IN TIME OF MAJOR CATIONS
WHITE RIVER FROM ABOVE HELLS HOLE CANYON TO BELOW ASPHALT WASH
OCTOBER 1976 - SEPTEMBER 1977

vtn

FIGURE 9



VARIATION IN TIME OF MAJOR ANIONS

WHITE RIVER FROM ABOVE HELLS HOLE CANYON TO BELOW ASPHALT WASH

OCTOBER 1976 – SEPTEMBER 1977

vtn

FIGURE 10

lower during high streamflow than during baseflow (0.27 mg/l vs. 0.4 mg/l). There was an unusually high concentration of fluoride measuring 2.0 mg/l on July 20, 1977 at station 09306700.

Biochemical Constituents

1) Dissolved Oxygen and Chemical Oxygen Demand: The range of concentrations of dissolved oxygen was about the same as during the Baseline study during high streamflow (11.6 to 5.0 mg/l vs. 11.7 to 2.4 mg/l), but during baseflow, the minimum value was less than during the Baseline study (5.4 mg/l vs. 6.4 mg/l). Maximum values occurred during the winter, as before. There was little variation between stations. Values of chemical oxygen demand were relatively steady throughout the year except for an increase in July (77 mg/l vs. annual mean of 34 mg/l). This increase is probably due to thunderstorm runoff washing organic matter into the White River. The values during the year are slightly higher in general than during the Baseline study (34 mg/l vs. 21 mg/l). There was a value of 90 mg/l on January 6, 1977 at station 09306500 that seems to be anomalous. Otherwise, there was little variation between stations.

2) Other: The concentration of dissolved organic carbon was slightly lower during high streamflow than during baseflow (3.9 mg/l vs. 7.2 mg/l). Concentrations of chlorophyll A and B were highest during October 1976 and the range of values was similar to the range during the Baseline study (13.5 to 0.000 ug/l vs. 13.0 to 0.00 ug/l for chlorophyll A, and 7.35 to 0.000 ug/l vs. 15.0 to 0.00 ug/l for chlorophyll B). There was little variation between stations.

Macronutrients

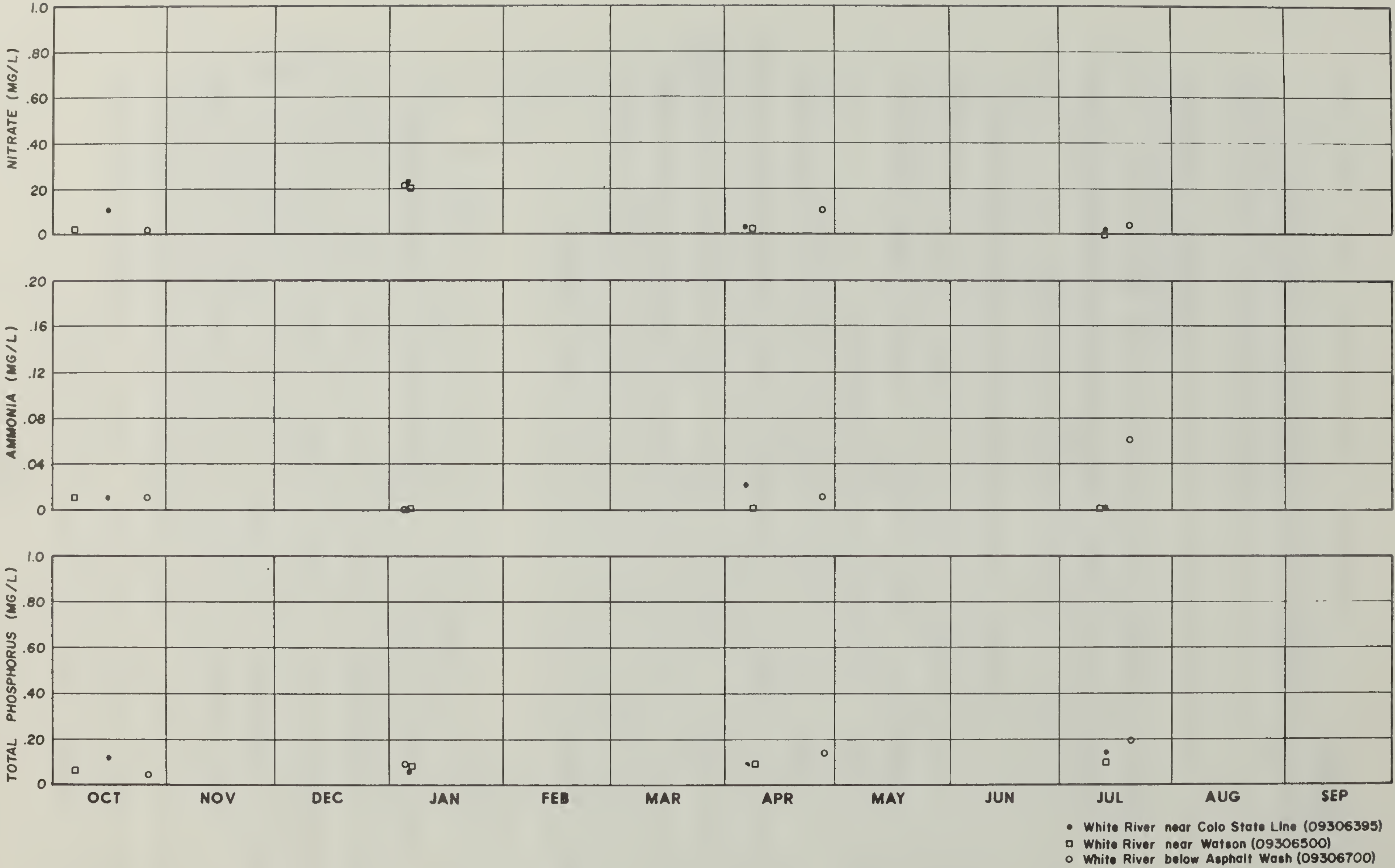
1) Nitrate, Ammonia: The concentration of nitrate was at a maximum during January 1977 (0.22 mg/l) and remained low during the rest of the year except for an increase in late April (0.10 mg/l). Levels of ammonia were low throughout the year. They did not show a rise in January as in the Baseline study. Both of these constituents showed little variation between stations. The data are shown in Figure 11.

2) Total Phosphorus: The concentrations varied directly with streamflow as in the Baseline study. The range of values was about the same during baseflow and high streamflow. There was little variation between stations. The data are shown in Figure 11.

3) Other: Levels of nitrite were very low throughout the year. Concentrations of Kjeldahl nitrogen varied directly with streamflow as in the Baseline study. The highest levels occurred in late April during high streamflow and in July after thunderstorm runoff (0.8 mg/l in late April and 1.1 mg/l in July vs. annual mean of 0.54 mg/l). There was little variation between stations for both of these constituents.

Micronutrients

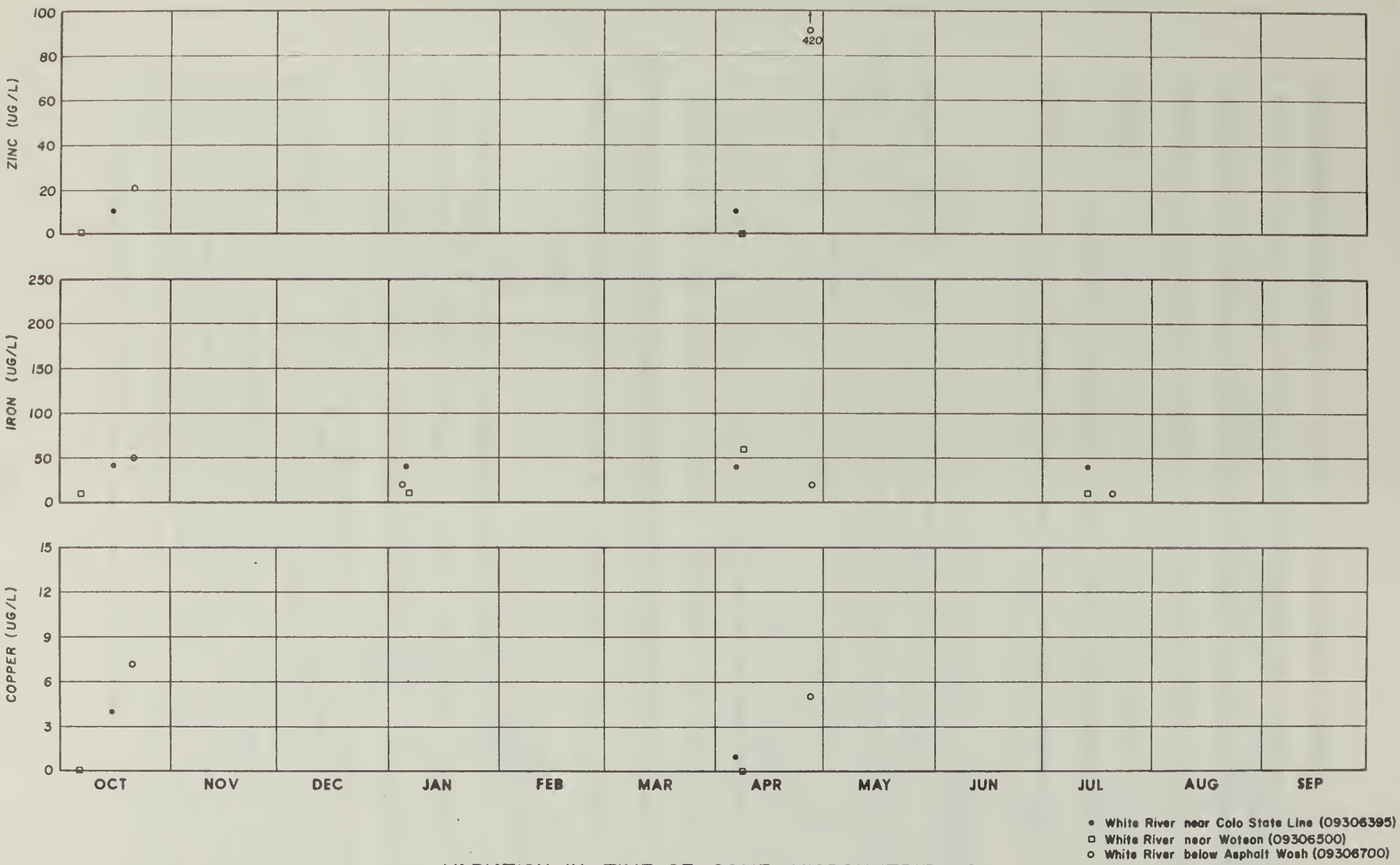
1) Zinc, Iron, Copper: These data are shown in Figure 12. The sinc concentration of 420 ug/l on April 27, 1977 at station 09306700 appears to be anomalous. Except for this value, the range of values for these three constituents is about the same as in the Baseline study. The concentration of copper remained about the same throughout the year. The data for zinc and iron does not seem to show clear relationships between concentration levels of these constituents and time of year sampled or location where the sample was taken. However, the amount of data available is limited, especially during high streamflow.



VARIATION IN TIME OF REPESENTATIVE MACRONUTRIENTS
WHITE RIVER FROM ABOVE HELLS HOLE CANYON TO BELOW ASPHALT WASH
OCTOBER 1976 - SEPTEMBER 1977

vtn

FIGURE 11



VARIATION IN TIME OF SOME MICRONUTRIENTS
WHITE RIVER FROM ABOVE HELLS HOLE CANYON TO BELOW ASPHALT WASH
OCTOBER 1976 - SEPTEMBER 1977

vtn

FIGURE 12

2) Other: Concentration levels of silica and molybdenum varied little throughout the year and the ranges of value were about the same as in the Baseline study. Concentrations of boron and manganese reached higher levels during July when the streamflow was very low than during the rest of the year (140 ug/l vs. annual mean of 76 ug/l for boron, and 30 ug/l vs. annual mean of 9.8 ug/l for manganese). There was little variation between stations for these constituents.

Trace Metals

The ranges of concentrations of aluminum, lead, lithium, vanadium, and chromium remained about the same as during the Baseline study. Barium and mercury were undetected in all samples. Concentrations of selenium and cadmium were very low.

The maximum concentration of lithium at each station occurred in July during very low streamflow (30 ug/l vs. annual mean of 16.9 ug/l). The concentrations of the rest of the constituents showed little variation with the time of year sampled and the location were the sample was taken.

Trace Non-metals

1) Arsenic, Phenol: Concentrations of both constituents were relatively constant at all stations. The range of values for both was about the same as in the Baseline study (1 to 0 ug/l vs. 4 to 0 ug/l for arsenic, and 3 to 1 ug/l vs. 14 to 0 ug/l for phenols).

2) Pesticides: There are no data available at station 09306700. At station 09306395 on October 15, 1976, the concentrations of DDE and DDT in bottom material were 0.5 and 0.2 ug/kg, respectively. At station 09306500 on October 6, 1976, the concentration of DDE in bottom material was 0.3 ug/kg. Other pesticides were undetected at these stations.

Radioactive Constituents

Station	Date of Sample	Gross Alpha (ug/l)	Gross Beta as Cesium 137 (PC/l)	Gross Beta as Strontium 90 (PC/l)
09306395	10/15/76	<6.4	1.7	1.5
	04/06/77	<7.3	<2.0	<1.6
09306500	10/06/76	<7.7	2.5	2.1
	04/08/77	12.0	4.7	3.7
09306700	10/21/76	<9.7	<1.9	4.5
	04/27/77	5.5	3.5	2.8

The data are inconclusive as to whether there are relationships to streamflow or relationships between stations. The ranges of values for these constituents were slightly less than the ranges of values during the Baseline study (12.0 to 5.5 ug/l vs. 35.0 to 3.7 ug/l for gross alpha, 4.7 to 1.7 PC/l vs. 13.0 to 2.8 PC/l for gross beta as Cesium 137, and 4.5 to 1.5 PC/l vs. 25.0 to 1.6 PC/l for gross beta as Strontium 90).

Water Quality: Evacuation Creek (Station No. 09306430)

General Characteristics

1) Dissolved Solids:

Date	Concentration (mg/l)
January 18, 1977	3560
April 8, 1977	3680
July 5, 1977	1630
July 6, 1977	842
October 28, 1977	3520

The low value on July 6 was similar to the minimum value during the Baseline study (842 mg/l vs. 793 mg/l). It occurred during thunderstorm runoff and was probably caused by dilution. The values for January, April and October 1977 were about the same as those during the Baseline study.

2) Suspended Sediment: Data are not available at this time.

3) pH: The range was 7.1 to 8.1 throughout the year. This is a continuation of the trend begun during the 1976 water year.

4) Temperature and Specific Conductance: Data are not available at this time.

5) Other:

Date	Alkalinity (ug/l)	Total Hardness (mg/l)	Noncarbonate Hardness (mg/l)
January 18, 1977	449	1200	750
April 8, 1977	450	1100	680
July 5, 1977	310	550	240
July 6, 1977	98	250	150
October 28, 1977	420	1100	710

The low values were again caused by dilution from thunderstorm runoff. The values from the rest of the year showed little variation as in the Baseline study.

Major Cations

1) Calcium, Magnesium, Sodium: The ranges of values were similar to those previously measured during the Baseline study. The concentrations of these cations paralleled the concentration of dissolved solids as in the Baseline study.

2) Other: Sodium adsorption ratio, percentage sodium, and levels of potassium and strontium remained about the same as during the Baseline study.

Major Anions

1) Bicarbonate, Chloride, Sulfate: The ranges of values were similar to those previously measured during the Baseline study. The concentrations of these anions also paralleled the concentration of dissolved solids as in the Baseline study.

2) Other: Carbonate levels were below the detection limit throughout the year. Concentrations of fluoride, sulfide, and bromide were similar to those during the Baseline study.

Biochemical Constituents

1) Dissolved Oxygen and Chemical Oxygen Demand: The range of values for both of these parameters were similar to those during the Baseline study.

2) Other: The concentrations of dissolved organic carbon and Chlorophyll A and B during baseflow were lower than those during the Baseline study (11 mg/l vs. 24 mg/l for dissolved organic carbon, 0.000 ug/l vs. 3.1 ug/l for Chlorophyll A, and 0.000 ug/l vs. 1.65 ug/l for Chlorophyll B). The reason for these lower levels is probably because there was much less surface runoff during the 1977 water year to carry organic matter into Evacuation Creek.

Macronutrients

1) Nitrate, Ammonia: Concentrations of nitrate were considerably less throughout the year than during the Baseline study (0.03 mg/l vs. 0.22 mg/l). Levels of ammonia were similar to values during the Baseline study. Nitrate and ammonia continued the trend established during the Baseline study of having higher concentrations during high streamflow than during baseflow.

2) Total Phosphorus: Concentrations of total phosphorus were much lower than during the Baseline study (0.017 mg/l vs. 0.34 mg/l). Phosphorus appeared to be continuing to follow the trend established during the Baseline study of having higher concentrations during high streamflow than during baseflow.

3) Other: Concentrations of nitrite were below the detection limit throughout the year. Concentrations of Kjeldahl nitrogen varied. The concentrations of these macronutrients were generally lower throughout the 1977 water year than during the Baseline study (0.00 mg/l vs. 0.02 mg/l for nitrate and 0.61 mg/l vs. 2.05 mg/l for Kjeldahl Nitrogen). This is probably because the 1977 water year had subnormal surface runoff and the proportion of groundwater inflow to streamflow was more than during the Baseline study. Groundwater would contain much lower concentrations of these macronutrients than surface water.

Micronutrients

Zinc had a higher maximum concentration than during the Baseline study (110 ug/l vs. 70 ug/l). The ranges of values for iron, copper, boron, manganese, molybdenum, and silica were about the same as previously. Iron showed a direct relationship to streamflow as before. Boron showed higher values during baseflow than during high streamflow as before, but manganese did not show this same trend. The values of copper, molybdenum, and silica were steady throughout the year as in the Baseline study. The relationship of zinc to streamflow was unclear.

Trace Metals

The range of concentrations of aluminum, lead, vanadium, chromium, barium, selenium, cadmium, and mercury were generally lower than values during the Baseline study. The range of concentration of lithium was about the same during baseflow as before. It is difficult to detect trends relating to streamflow for these constituents because no analyses were done for samples during high streamflow from October 1976 to October 1977.

Trace Non-metals

1) Arsenic, Phenol: The concentrations of these constituents were about the same as in the Baseline study and showed little variation between samples taken on April 8 and October 28, 1977.

2) Pesticides: There are no data available.

3) Detergents (MBAs): Concentrations during baseflow were similar to those during the Baseline study.

Radioactive Constituents

Date	Gross Alpha (ug/l)	Gross Beta as Cesium 137 (PC/l)	Gross Beta as Strontium 90 (PC/l)
April 8, 1977	<53	32	25
October 28, 1977	<33	21	18

There are not enough data to draw any conclusions concerning trends of these constituents.

Water Quality: Dry Washes

No water quality samples were obtained during the flow events at station 09306610. Modification of the single-stage sampler at this site will be done for the 1978 water year to enhance opportunistic data collection.

Water quality data for stations 09306405 and 09306625 are not available at this time.

4.1.1.4 Conclusions:

Comparison of Chemical and Physical Composition Between Baseline and Interim Periods

White River: Streamflow during the Interim period was considerably different than during the Baseline period. Peak streamflow was less during the Interim period than during the Baseline study. In July very low values of streamflow occurred twice. There was a period of rapidly rising stage after the first low level, then streamflow gradually reached a very low level through most of the rest of July. Suspended sediment concentration, which varies directly with streamflow, reached a maximum value higher than any value during the Baseline study during this period of rapidly rising stage. This is because the proportion of thunderstorm runoff to baseflow was much higher than usual. Water quality samples were taken during the second period of very low flow during July. The data from these samples showed that constituents which vary inversely with streamflow, such as dissolved solids, reached higher maximum values than any values during the Baseline study. These results are expected considering the very low level of streamflow. However, based on the data base at station 09306500, streamflow would be rarely expected to reach minimum values similar to those in 1977. The data from the rest of the quarterly water quality samples showed no significant differences from comparable data during the Baseline study.

Evacuation Creek: Water quality samples were taken during a period of thunderstorm runoff in early July. The data from these samples showed that constituents which vary inversely with streamflow, such as dissolved solids, had minimum values lower than any values during the Baseline study. This is because of dilution from thunderstorm runoff.

Water quality data from samples taken during the rest of the Interim period showed no significant differences from comparable data during the Baseline study.

Comparison of Chemical and Physical Composition Between Stations on the White River

Streamflow variations between stations 09306395, 09306400, 09306500 and 09306700 along the White River are insignificant. Correlations of concurrent streamflow data between stations 09306395 and 09306400 were high.

In general, there are no significant differences in water quality between stations 09306395, 09306500, and 09306700. The data for such constituents as zinc, iron, and aluminum seem to show considerable differences between stations, but when the precision of the measurement (to the nearest 10 ug/l) is considered, the differences become insignificant. Also, the amount of data for these constituents is more limited than in the Baseline study. The marked difference in pH measurements at station 09306700 was due to a systematic error in the method used for measurement, and the adjusted readings are similar to the measurements at the other stations. The data for radioactive constituents are inconclusive as to whether there are trends between stations. More data are needed before such conclusions could be made.

4.1.2 Deep Aquifer Water

The aquifer monitoring program, like the surface water program, is based on a combination of WRSP and USGS efforts. Division of responsibility is shown in Table 9.

4.1.2.1 Objectives. The objectives of this monitoring element are to extend water level data so as to provide continuity between the Baseline work and future monitoring periods, and to investigate long-term water level trends.

4.1.2.2 Methods. Water levels were continuously monitored by the USGS at P-1, P-2 Upper and P-2 Lower, and by the WRSP at P-3. Float and time activated digital punch recorders were recording the level every hour at P-1, P-2 Upper, P-2 Lower, and P-3. For quality assurance, WRSP manually checked the water level at P-3 once per month.

Manual water level readings were taken by WRSP at G-8, G-8A, G-5, G-10, G-11, G-15, G-21, and P-4 in January and June 1977, which corresponded to the periods of minimum and maximum water levels, respectively, as found in the Baseline period.

4.1.2.3 Results to Date. The continuous hydrographs for wells P-1, P-2 Upper, P-2 Lower, and P-3 are shown in Figures 13 through 16. Semiannual water level measurements for the other deep wells are shown in Table 10. The data show that the ground water surface in all three aquifers (Upper, Bird's Nest, and Douglas Creek) is remaining steady at

TABLE 9

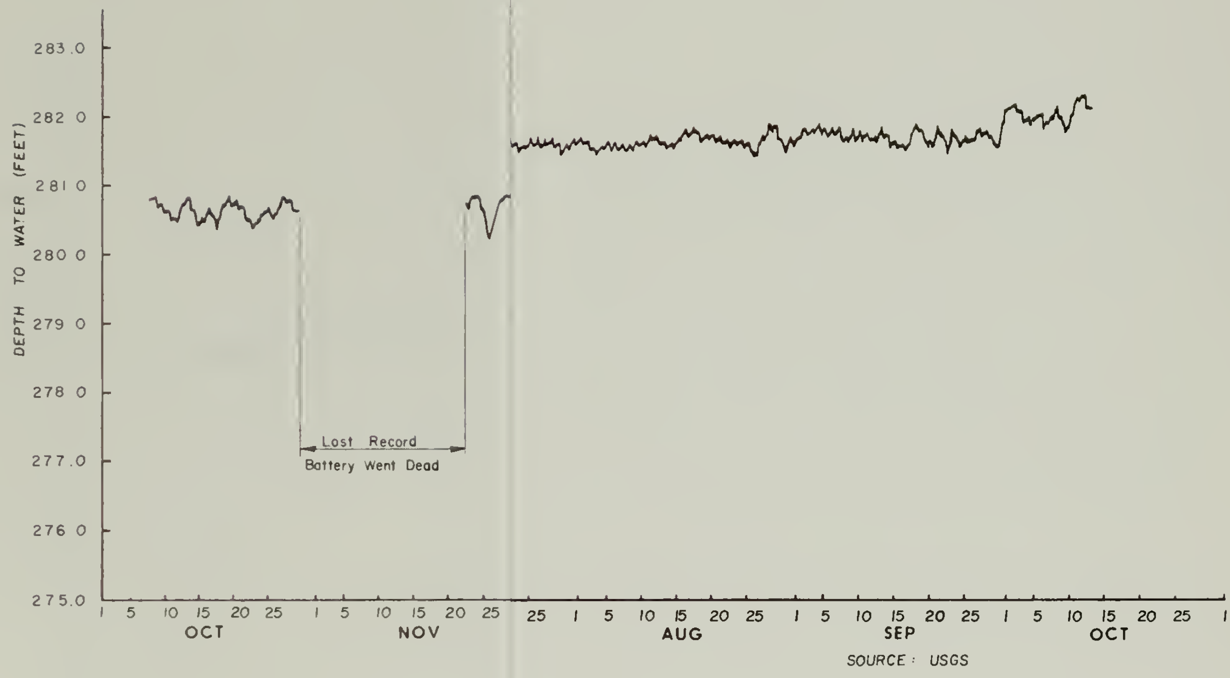
RESPONSIBILITY FOR GROUND WATER MONITORING

ACTIVITY	RESPONSIBILITY
Deep Aquifer	
- P-1, P-2U, and P-2L continuous	USGS
- P-3 continuous	VTN
- G-8, 8A, 5, 10, 11, 15, 21, and P-4 semi-annually	VTN
Alluvial Wells	
- Quarterly quality samples, monthly water-level samples through Dec. 1976	USGS
- AG-3, 4, and 8 water-level, temperature and SC monthly through Jan. 1977 and quarterly in Feb.-Oct.	USGS
- AG-1 and AG-6, quality samples once at high flow and once at low flow, and monthly water-level samples, in Feb.-Oct.	VTN & USGS

TABLE 10

DEEP WELL WATER LEVELS

WELL	DATE	DEPTH TO WATER (FT)
G-8	1/17/77	53.20
	6/22/77	55.00
G-8A	1/17/77	43.60
	6/22/77	43.30
G-5	1/17/77	460.64
	6/22/77	459.95
G-10	1/17/77	320.85
	6/22/77	321.95
G-11	1/17/77	468.18
	6/22/77	469.50
G-15	1/17/77	510.20
	6/22/77	509.50
G-21	1/17/77	430.85
	6/22/77	430.00
P-4	1/17/77	265.69
	6/22/77	265.73



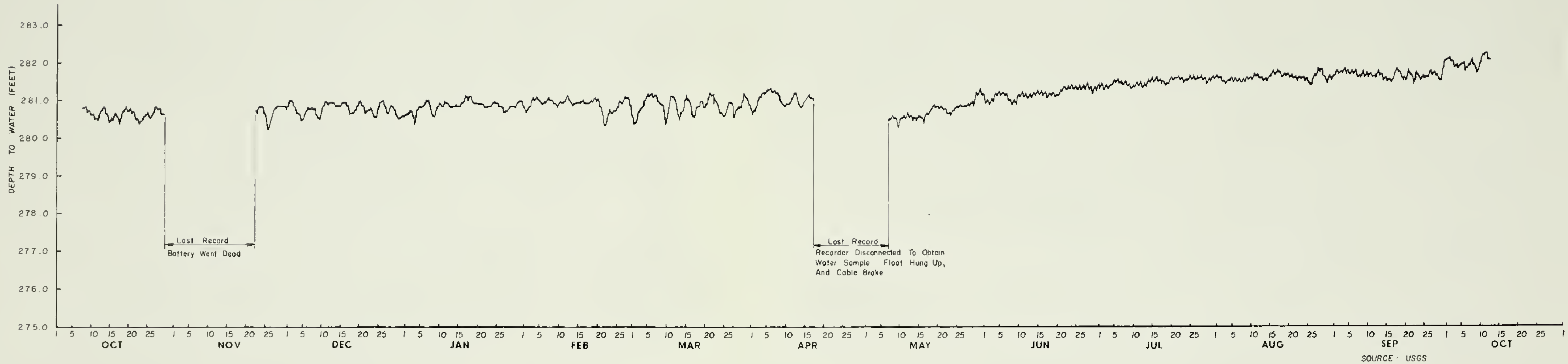
vtn

FIGURE 13

TABLE 10

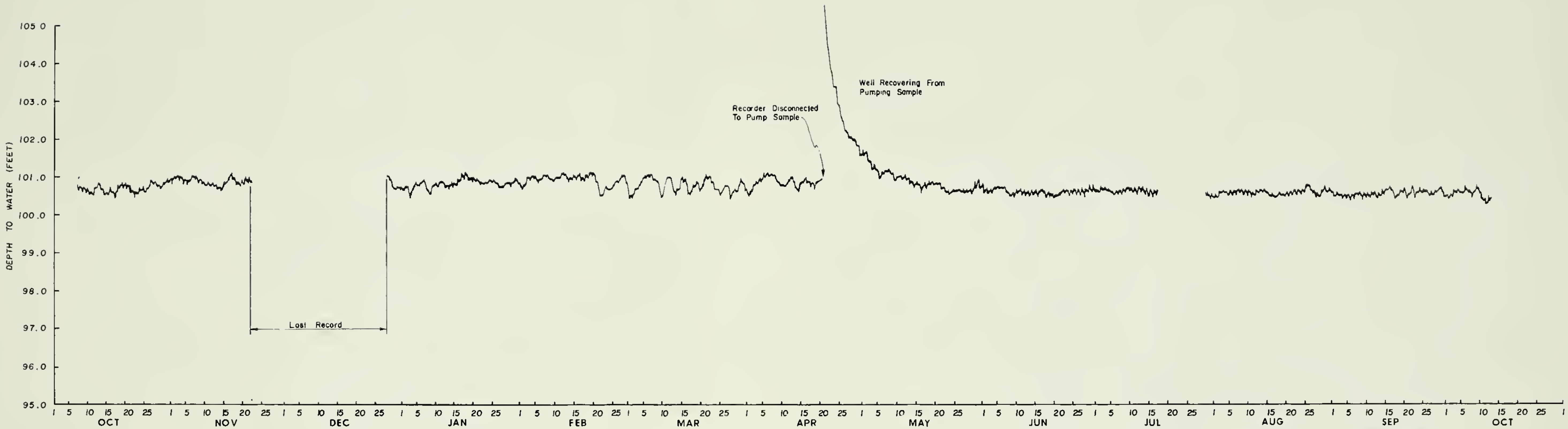
DEEP WELL WATER LEVELS

WELL	DATE	DEPTH TO WATER (FT)
G-8	1/17/77	53.20
	6/22/77	55.00
G-8A	1/17/77	43.60
	6/22/77	43.30
G-5	1/17/77	460.64
	6/22/77	459.95
G-10	1/17/77	320.85
	6/22/77	321.95
G-11	1/17/77	468.18
	6/22/77	469.50
G-15	1/17/77	510.20
	6/22/77	509.50
G-21	1/17/77	430.85
	6/22/77	430.00
P-4	1/17/77	265.69
	6/22/77	265.73



CONTINUOUS MONITORING WELL P-1

OCTOBER 1976 - OCTOBER 1977



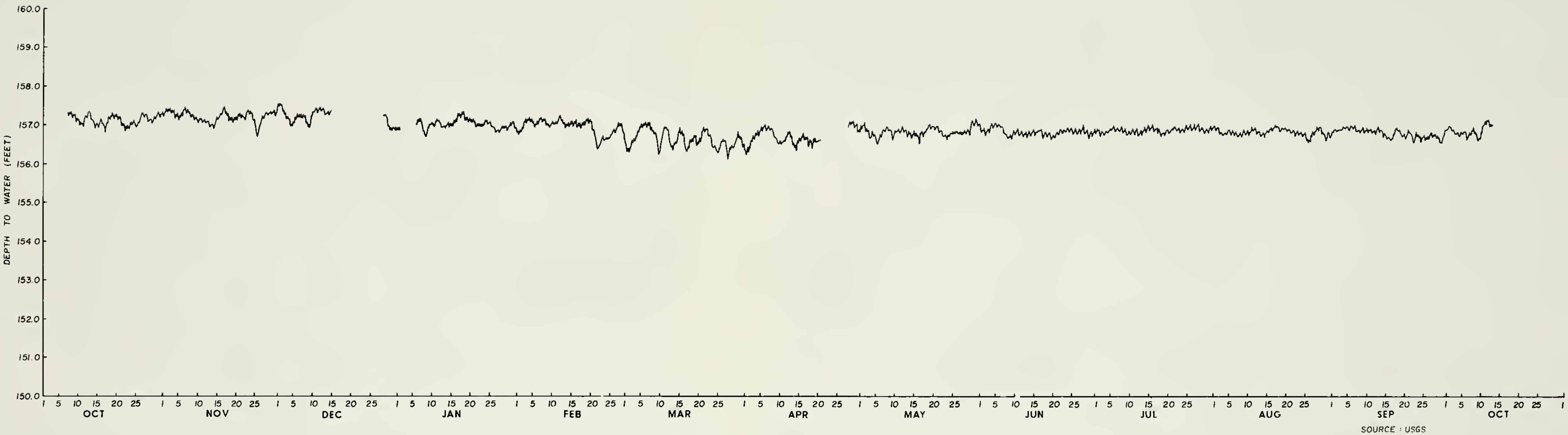
SOURCE · USGS

CONTINUOUS MONITORING WELL P-2 UPPER

OCTOBER 1976 – OCTOBER 1977

vtn

FIGURE 14

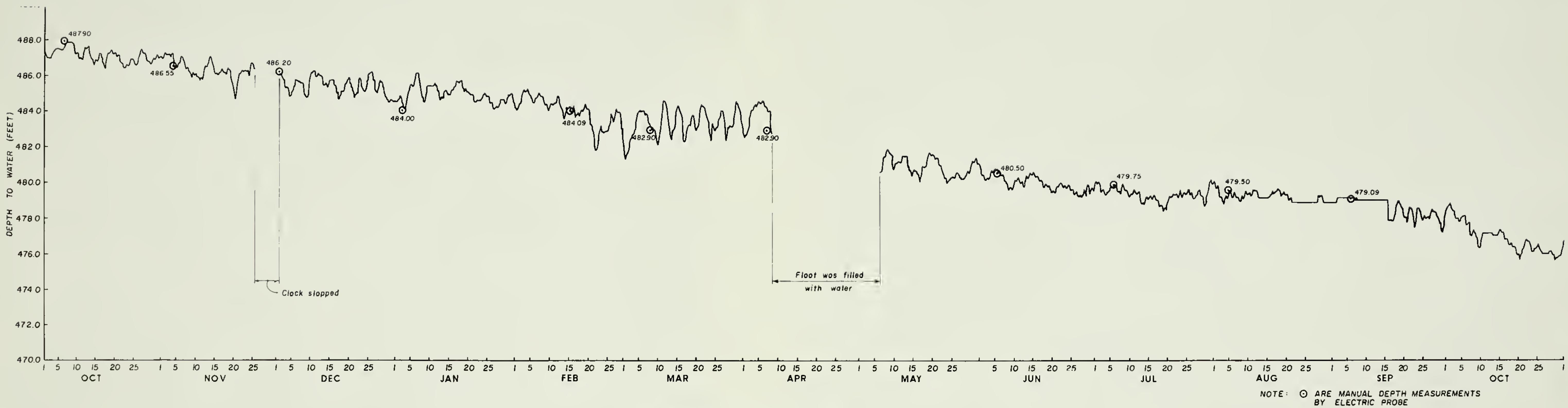


CONTINUOUS MONITORING WELL P-2 LOWER

OCTOBER 1976 – OCTOBER 1977

vtn

FIGURE 15
4-45



CONTINUOUS MONITORING WELL P-3

OCTOBER 1976 - OCTOBER 1977

FIGURE 16

the same levels as during the Baseline period, except at well P-3. The water level in this well rose at a steady rate throughout the Interim period of October 1976 through October 1977. The rise in water level during this period was about 3.66 meters (12 ft). The data at well P-3 during the Interim period appear to be anamalous. Without data from further testing at this well, no explanation of this condition can be made at this time.

4.1.2.4 Conclusions. The water levels at corresponding sites have remained steady during the Interim monitoring period at levels reached during the Baseline period, with one exception at well P-3. The condition at this well appears to be anomalous, and no explanation can be made at this time without more data.

4.1.3 Alluvial Ground Water

The USGS Water Resources Division incorporated several WRSP wells into their own program. The program discussed below, therefore, was carried out by the USGS; and represents the program as initiated October 1, 1976, and with modifications effective in January 1977. Table 9 presents the division of responsibilities of this program.

4.1.3.1 Objectives. The objectives of the program are to extend the data base in regard to alluvial well water levels and water quality, and to begin identifying long-term trends of these two parameters.

4.1.3.2 Methods. Monthly water level, temperature, and specific conductance measurements were made through December 1976 at eight locations in five drainage areas:

1. White River (AG-1 Upper/Lower and AG-3 Upper/Lower)
2. Hell's Hole Canyon (near mouth Upper/Lower)
3. Evacuation Creek (AG-8, near Park Canyon Upper/Lower, and above Missouri Creek Lower)
4. Southam Canyon (AG-6 Upper/Lower)
5. Asphalt Wash (AG-4)

Water quality samples were withdrawn quarterly through December 1976 and analyzed pursuant to the schedule in Table 11. Additional water quality samples were to be withdrawn from AG-1, AG-3, AG-4, AG-6, and AG-8 if the conductivity measurement was 20% higher than the maximum recorded value, or 20% lower than the minimum recorded value of record for a corresponding past period.

Frequency of sampling for the program was modified in January 1977. Effective that month, water level, temperature, and condictivity were measured quarterly. A water quality sample was taken once during the high flow period of 1977 by the USGS at AG-1, AG-3, AG-4, AG-6, and AG-8. Monthly water level, temperature, and conductivity measurements resumed at AG-1 and AG-6 during snowmelt and thunderstorm seasons (approximately February through October).

4.1.3.3 Results to Date.

Ground Water Levels

Alluvial well measurements are shown in Table 12.

White River: The range of static water levels for the AG-1 and

TABLE 11

OIL SHALE PROJECT - WATER QUALITY

GROUND WATER SCHEDULE - USGS SITES (REVISED DECEMBER 3, 1975)

Sodium	Iodide	Strontium
Aluminum	Lithium	Vanadium
Arsenic	Magnesium	Zinc
Boron	Manganese	Dissolved Solids
Barium	Molybdenum	Bicarbonate
Bromide	Nitrate & Nitrite	Carbonate
Calcium	Ammonia	Alkalinity
Cadmium	Total Kjeldahl Nitrogen	Hardness
Chloride	Phosphate	Organic Carbon (Dissolved)
Chromium	Total Phosphorus	*Gross Alpha & Beta
Copper	Lead	Radium 226
Fluoride	Sulfate	**Temperature
Iron	Sulfide	**Conductivity
Mercury	Selenium	**pH
Potassium	Silica	

* If gross alpha activity is measured at greater than 4 picocuries/liter, then analysis for radium 226 and for natural uranium will be done. If gross beta activity is greater than 100 picocuries/liter, then analysis for Sr^{90} and Ce^{137} will be done.

** Field Measurements

TABLE 12

ALLUVIAL WELL MEASUREMENTS

OCTOBER 1976 - OCTOBER 1977

WELL		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY		JUN	JUL		AUG		SEP	OCT
AG-1 Upper	Date	15	22	29	30	15	30				1			2	10	19	18
	Level	13.44	13.65	11.17	10.39	10.96	13.54				13.80			14.50	14.45	14.10	13.76
	Temp.					3.0	7.0				10.2				12.5	14.5	14.5
	Cond.				1,800	1,420	1,300				1,150				850	750	910
AG-1 Lower	Date	15	22	29	31	15	30				1			2	10	19	18
	Level	13.55	13.54	11.35	10.49	10.95	13.43				12.65			14.09	14.40	14.15	13.66
	Temp.	10.5	10.0	9.5		9.5	9.0				10.2					15.2	11.0
	Cond.	1,150	1,125	850	1,050	920	920				1,400					500	880
AG-3 (WRSP)	Date	19	23	27	28	8			5	26				1	12		18
	Level	12.36	12.29		11.74	11.43			11.89	12.49				12.69	13.19		12.45
	Temp.	12.5	11.0	9.0	9.0	10.0			9.0								12.0
	Cond.	3,800	3,590	3,300	3,300	3,340			3,300								3,550
AG-3 Upper (USGS)	Date	7	23	27	28	8			5	26					12		18
	Level	11.71	11.77	11.65	11.26	10.96			11.38	11.95					12.82		12.02
	Temp.	14.5	12.5	11.0		10.5			10.5								13.0
	Cond.	3,000	2,600	2,400		2,640			2,500								2,500
AG-3 Lower (USGS)	Date	7	23	27	28	8			5	26					12		18
	Level	12.58	12.66	12.44	12.09	11.76			12.20	12.83					13.52		12.77
	Temp.	13.5	11.0		11.0	10.5			11.0								13.0
	Cond.	4,600	4,600		4,100	4,300			4,300								4,220
AG-4	Date	19	22	28	28	8			5					1			18
	Level	30.36	30.34	30.28	29.67	29.60			29.95					31.27			30.90
	Temp.	12.5	12.5		12.0	12.0			11.0								13.0
	Cond.	2,150	2,100		1,400	1,400			1,370								1,330
AG-6 Upper	Date	12	22	28	28	8	30			27	1	6	29		9	15	18
	Level	19.00	18.96	18.90	18.44	18.38	18.83			19.20	19.20	19.80	19.69		19.25	18.90	19.33
	Temp.	13.5	14.0	11.0	11.0	12.0	12.0			15.0	15.5	14.2			15.5	14.5	13.0
	Cond.	4,000	3,400	3,280	2,100	3,000	2,300			2,100	2,050	1,800			1,900	1,800	2,000
AG-6 Lower	Date	12	22	28	28	8	30			27	1	6	29		9	15	18
	Level	17.77	17.70	17.68	17.19	17.13	17.57			18.80	Dry	18.00	18.41		18.70	18.25	18.05
	Temp.	13.5	12.0	12.0	12.0	12.0	12.0			15.2		16.0			19.5	14.5	12.5
	Cond.	6,900	5,900	6,480	4,900	6,200	5,600			2,000		2,000			1,800	1,800	4,300
AG-8	Date	15		29	31	15					*8			1			13
	Level	5.14		Frozen	Frozen	Frozen					4.95			5.45			4.51
	Temp.	14.0															13.0
	Cond.	5,200															4,430
Hells Hole (Upper)	Date	14	29	29	30	15		7								14	12
	Level	16.87	16.90	16.94	17.01	16.99		17.06								17.40	17.25
	Temp.																12.0
	Cond.																2,570
Hells Hole (Lower)	Date	14	29	29	30	15		7								14	12
	Level	17.46	17.51	17.49	17.60	17.60		17.70								18.09	17.84
	Temp.																12.0
	Cond.																2,300
Evac Creek Above Missouri Creek (Lower)	Date	14	29		30	15		8								14	12
	Level	28.6	27.8		27.15	27.01		26.95								28.64	28.40
	Temp.	12.0	10.0		10.0	11.0		12.5									10.5
	Cond.	4,600	4,200		3,700	4,180		4,190									4,200
Evac Creek Near Park Canyon (Upper)	Date	14	29		31	15		7							31		12
	Level	14.87	14.26		14.17	13.98		12.68							14.39		14.53
	Temp.	14.0	8.5			9.5		9.5									11.0
	Cond.	5,200	4,200		4,000	4,300		4,370									4,520
Evac Creek Near Park Canyon (Lower)	Date	14	29		31	15		7							31		12
	Level	15.86	15.42		15.27	15.05		14.02							15.66		15.67
	Temp.	14.0	9.0			10.0		11.0									10.5
	Cond.	4,600	4,200		3,950	4,200		4,060									4,200

*NOTE: Concrete control for surface water station was being done. Later water levels might be affected.

NOTE: Static water level is in feet.
Temperature is in °C.
Specific conductance is in μmhos/cm.

AG-3 wells was similar to the range during the Baseline study. Water levels were highest during December, January, and February and lowest during August. There was little difference between measurements in October 1976 and October 1977 for each of these wells.

Hell's Hole Canyon: The static water levels of both the upper and lower wells near the mouth of Hell's Hole Canyon showed a gradual decline from October 1976 through September 1977, and a slight rise in October 1977. The differences for both wells between October 1976 and October 1977 was small however.

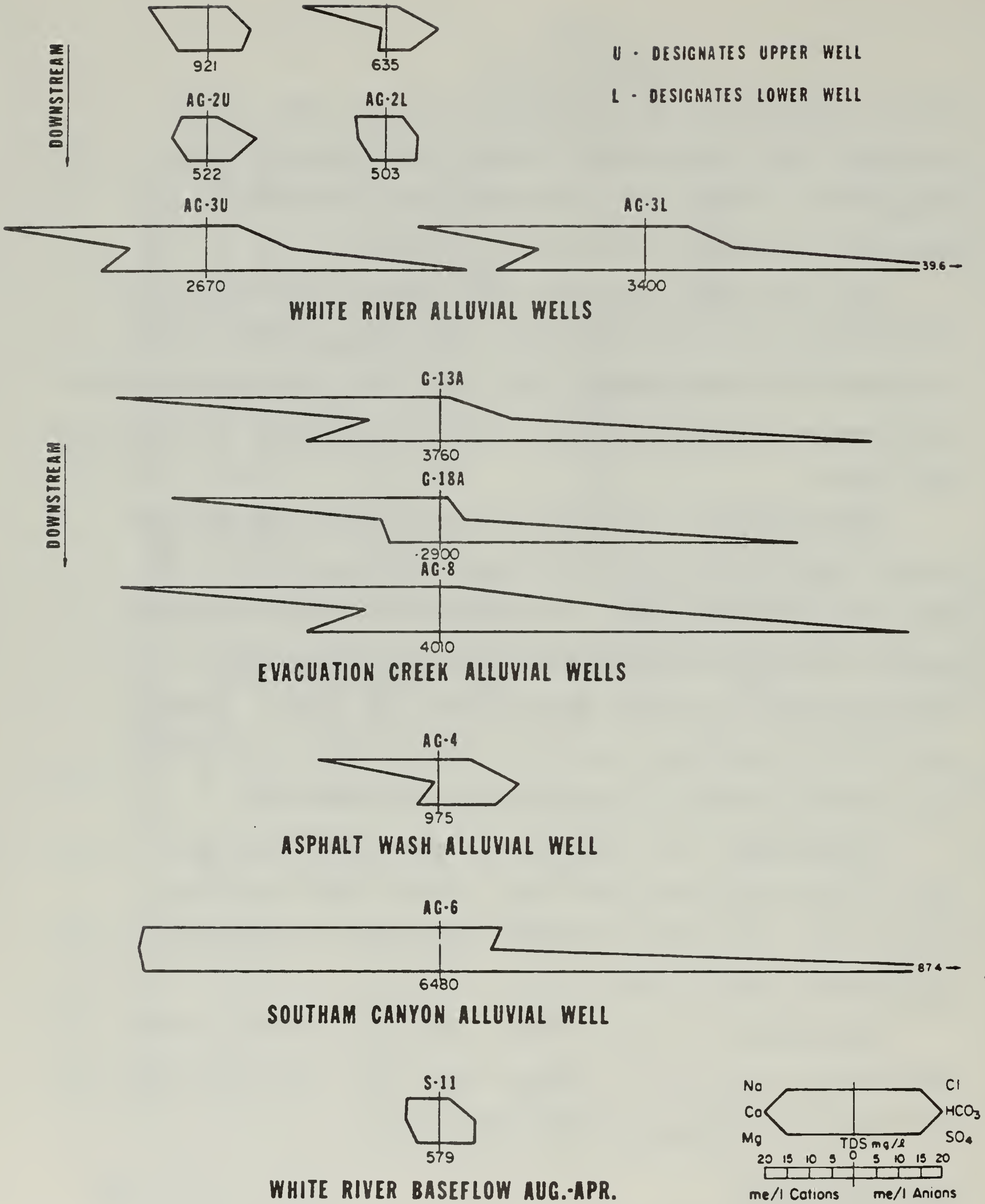
Evacuation Creek: The ranges of static water levels for AG-8 and the wells near Park Canyon and above Missouri Creek were similar to the ranges during the Baseline study. Water levels were highest during April and lowest during September and October. There was some difference between measurements in October 1976 and October 1977 at AG-8. Concrete control for the surface water station near AG-8 was done in June 1977 and this might have affected the later measurement in October 1977.

Southam Canyon: The ranges of static water levels of the AG-6 upper and lower wells were slightly lower than the ranges during the Baseline study. Water levels were highest during January and February and lowest during June and July.

Asphalt Wash: The range of static water level at AG-4 was slightly lower than the range during the Baseline study. Water levels were highest during January and February and lowest during August.

Ground Water Quality

Alluvial well measurements are shown in Table 12. A correction to Figure II-87 of the Final Environmental Baseline Report is shown in Figure 17.



Source: FEBR, 1977
FIGURE II-87
PAGE II-159

NOTE: This scale is incorrect. The numbers (me/l) as shown should be divided by two.

ALLUVIAL GROUND WATER QUALITY
WHITE RIVER SHALE PROJECT - JUNE 1976

FIGURE 17

White River: The data for well AG-1 Upper are questionable. This well was drilled too shallow and cannot be bailed properly before sampling because there is usually only a small amount of water in the well and recovery is slow. The distribution and concentrations of major cations and anions from samples at well AG-1 Lower were similar to results during the Baseline study.

Samples from the three wells at the AG-3 location showed similar distributions of major cations and anions. However, specific conductance and concentrations of major cations and anions were different between each of the three wells. These relationships were similar to results from the Baseline study. Well AG-3 Upper (USGS) is by iteself and further from the channel of the White River than the other two wells. Specific conductance and the concentration of dissolved solids were less at this well than at the other two wells. A possible cause for this condition would be that horizontal flow of water has caused a greater concentration of salts in the alluvium nearer the river channel. Wells AG-3 Lower (USGS) and AG-3 Upper (WRSP) are close to each other and nearer the river channel than the other well. The lower well completed in bedrock had the highest specific conductance and concentration of dissolved solids. A possible cause for this condition would be that water reaching the lower well is affected by leaching from the bedrock surface.

Water quality has shown considerable differences between the AG-1 and AG-3 locations. Both the concentrations and the distribution of major cations and anions were different. Possible causes for differences in water quality at these locations were discussed in the Final Environmental Baseline Report. The alluvial water at AG-1 showed similarities to ground water from the Green River formation, whereas the source of the alluvial water at AG-3 is probably the Uinta formation.

Hell's Hole Canyon: The water quality data from the upper and lower well near the mouth of Hell's Hole Canyon showed some variation in comparison to results from the Baseline study and in comparison of the two wells. There is hydrogen sulfide gas present in these wells and it probably causes a quality control problem. The data from samples of these wells is therefore inconclusive.

Evacuation Creek: The water quality data for the wells at AG-8, at Evacuation Creek near Park Canyon, and at Evacuation Creek above Missouri Creek were similar to results during the Baseline study. Specific conductance and the concentrations and distributions of major cations and anions were similar for all of these wells during the Interim period.

Southam Canyon: The water quality data from samples of the upper and lower wells at AG-6 showed a decrease in specific conductance and the concentration of dissolved solids during the Interim period. The distribution of major cations and anions was similar to the results of the Baseline study. This might indicate that the effect of the salts discharged in 1974 during drilling and pump tests at the upstream P-2 location is diminishing. The possible effects of these discharges were discussed in the Final Environmental Baseline Report.

The distribution of major cations and anions was similar between the upper and lower wells, however, the concentrations were considerably higher in samples from the lower well than in samples from the upper well. A possible cause for this condition might be that water reaching the lower well is affected by leaching from the bedrock surface.

Asphalt Wash: Water quality data from samples at well AG-4 during the Interim period were similar to results during the Baseline study.

4.1.3.4 Conclusions

Comparison of Water Level and Chemical Composition Between Baseline and Interim Periods

The static water levels for wells near the White River and Evacuation Creek showed no significant differences between the Baseline and Interim periods. The wells in Hell's Hole Canyon, Southam Canyon, and Asphalt Wash all showed a slight decline in static water level during the Interim period as compared to the Baseline period. This decline was probably caused by below normal recharge to these alluvial aquifers, since precipitation was less during the Interim period than the annual precipitation during the Baseline period.

There were no significant differences in the chemical composition of alluvial well samples during the Interim period as compared to the Baseline period, except at the AG-6 location. The differences in chemical composition at the AG-6 location were probably caused by a decreasing effect over time of the upstream discharges that occurred at the P-2 wells in 1974.

Comparison of Water Level and Chemical Composition Between AG-1 and AG-3

The fluctuation of static water level with respect to time was similar at the AG-1 and AG-3 locations. However, the wells at AG-1 had a much larger range of water levels than wells at AG-3 during the Interim period. The AG-1 wells are located in the alluvial fan of a south-draining canyon. Recharge of this alluvial aquifer is probably due to a combination of ground water flow and interflow. Recharge of the aquifer at the AG-3 location probably depends mostly on ground water flow. Recharge from interflow would show more fluctuation than recharge from ground water flow because interflow is generally affected more quickly by precipitation (or the lack of precipitation).

The chemical composition from water quality samples at these two locations showed large differences in distribution and concentrations of major cations and anions. These differences are probably caused by the geologic formations that the water comes in contact with (the Green River formation at AG-1 and the Uinta formation at AG-3).

Comparison of Chemical Composition Between Upper and Lower Wells

The lower wells showed higher specific conductance and higher concentrations of dissolved solids than the upper wells at AG-6 and AG-3. The distribution of major cations and anions were the same, though. The probable cause for this condition is that the water reaching the lower wells is affected by leaching from the bedrock surface. None of the other locations showed significant differences in chemical composition between upper and lower wells.

4.1.4 Precipitation/Evaporation

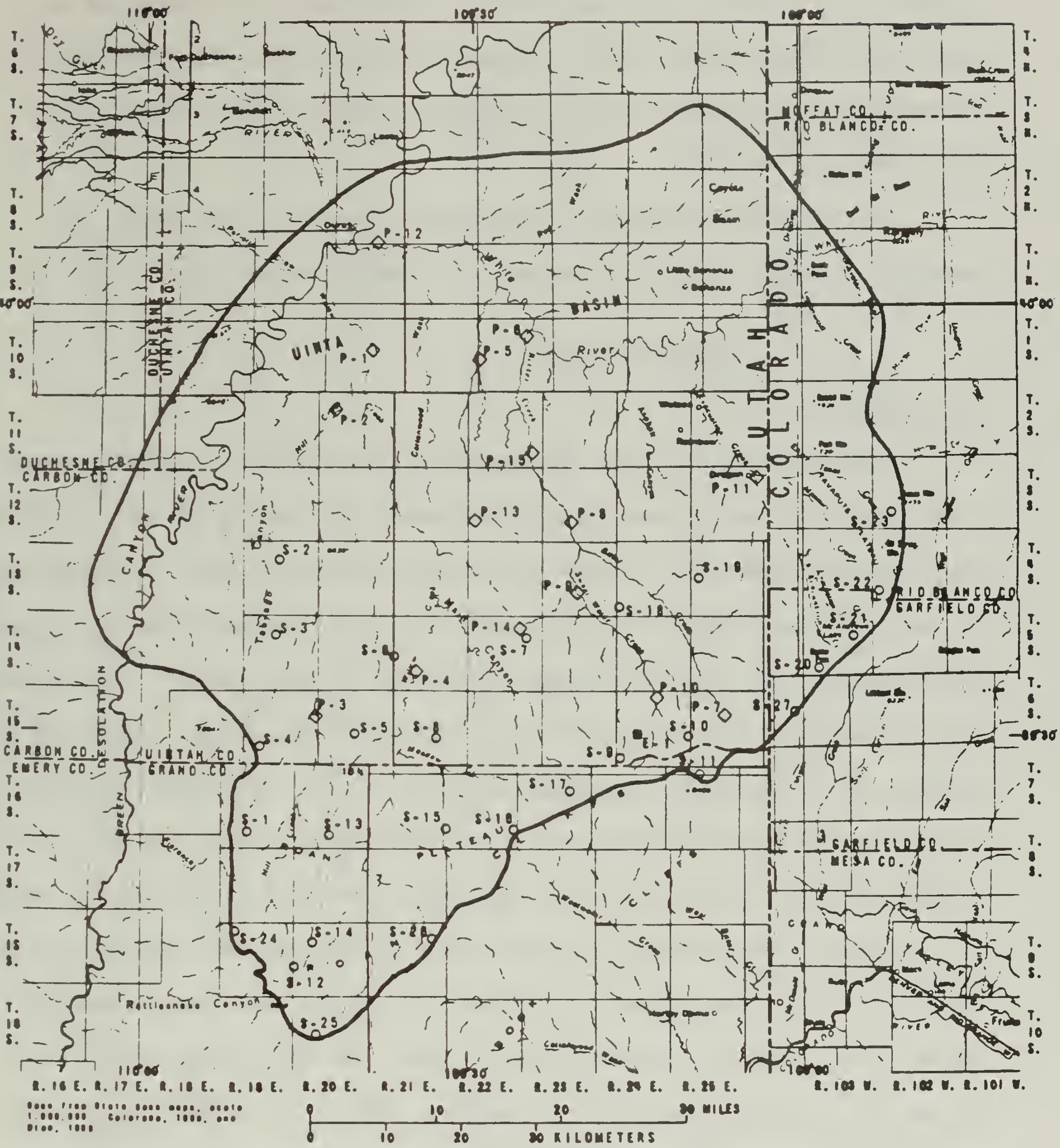
The following program was implemented during January 1977. The Interim Monitoring Program was modified from the Baseline program insofar as fewer sites are used.

4.1.4.1 Objectives. The objectives of the precipitation/evaporation program are to augment the USGS regional data collection network (see Figure 18), provide site specific information on precipitation and evaporation at the plant site and processed shale disposal area, and to place the Interim period in historic perspective.

4.1.4.2 Methods. Precipitation was measured by automatic gages at three locations beginning in April 1977. The plant site gage (AR-13) and at Southam Canyon site (AR-2) are operated year round. The other

FIGURE 18

REGIONAL USGS PRECIPITATION NETWORK



EXPLANATION

◇ P-3
Precipitation gage

○ S-1
Snow gage

■ E-1
Evaporation gage

Source: Utah Basic Data Release No. 29, 1977

Southam Canyon site (AR-9) was put into operation during April and was operated through October 1977. Standard storage gages were used at these three locations as well as at the mouth of Southam Canyon (RS-13) from April through October.

Evaporation was measured in Southam Canyon (EVP-2) and at the proposed plant site (EVP-13) during the freeze-free period.

4.1.4.3 Results to Date

Precipitation

Monthly precipitation data are shown in Table 13. Annual average precipitation from October 1976 to September 1977 was 15.24 cm (6.0 inches) which is only about sixty percent of normal for this area. In comparison to the Baseline study: fall and winter precipitation were much less; spring precipitation was less; and summer precipitation was greater. Summer was the period of maximum precipitation rather than the spring. There was an average of 26 precipitation events during the year. The most intense precipitation occurred on August 17, 1977 at ARA-2, where 2.79 cm (1.1 in) of rain fell in 75 minutes out of the total of 3.05 cm (1.2 in) for the day.

Winter precipitation was uniformly distributed over the project area. Spring precipitation was more at higher elevations than lower elevations. Summer precipitation was relatively uniform over all elevations. This supports the conclusion from the Baseline study that terrain is an important factor affecting rainfall, but at times slow-moving, intense, isolated storms cause precipitation to be uniform over all areas.

Regional USGS precipitation data from 35 gages (see Figure 18) show an annual average precipitation of about 17.7 cm (7 in) with a range of 11.10 to 33.02 cm (4.37 to 13.00 in). Most of the gages show the same

TABLE 13

PRECIPITATION RECORDS

1977 WATER YEAR

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT-MAR	APR-SEP	ANNUAL
RS-1	0.21	0	T												
RP-1	0.20	0	0.04												
RS-2							1.11	0.44	0.05	0.77	1.78	0.54		4.69 in (11.91 cm)	
ARA-2	0.10	0	T	0.30	0.30	0.50	1.20	0.50	0.10	0.90	1.90	0.20	1.20 in (3.05 cm)	4.80 in (12.19 cm)	6.00 in (15.24 cm)
RS-6	0.26	0	T												
RS-9	0.18	0	0.05				1.14	1.02	0.16	1.34	1.38	0.72		5.76 in (14.63 cm)	
ARS-9	0.20	0	0				1.40	0.90	0.30	1.20	1.50	0.30		5.60 in (14.22 cm)	
RS-12	0.10	0	T												
RS-13	0.16	0	0.03				0.98	0.47	0.15	1.28	1.19	0.76		4.83 in (12.27 cm)	
ARA-13 plant site	0.10	0	T	0.30	0.30	0.30	1.30	0.30	0.20	1.40	1.50	0.30	1.00 in (2.54 cm)	5.00 in (12.70 cm)	6.00 in (15.24 cm)
RS-13 plant site							1.11	0.60	0.21	1.09	1.37	0.50		4.88 in (12.40 cm)	

seasonal distribution of precipitation as the gages in the project area. Gages at higher elevations show greater precipitation, generally with increased precipitation during all seasons.

Evaporation

Data for pan evaporation at EVP-2 and EVP-13 from May through September 1977 are shown in Table 14. Total pan evaporation at EVP-2 for the 1977 growing season was slightly less than in 1975 and greater than in 1976. The difference in pan evaporation between these two stations seems to be greater than can be accounted for by elevation difference. Since there are no measurements at EVP-13 during the Baseline period, more data at EVP-13 is needed to derive an accurate relationship between the two stations.

A water balance at ARA-2 and EVP-2 for the 1977 growing season is shown in Table 15. Based on the findings from the Baseline study, total runoff was assumed to be negligible compared to precipiation. The same pan coefficient and the same range of values for the crop-use coefficient as in the 1975 water balance for Southam Canyon (from the FYEBR) were used for this water balance. The water deficit was 4 to 10% greater in 1977 than in 1975. The potential evaporation corresponds closely with regional consumptive-use factors as it did for 1975 in the FYEBR.

The only regional USGS evaporation gage was discontinued for the 1977 water year.

4.1.4.4 Conclusions

Comparison of Precipitation/Evaporation Measurements Between Baseline and Interim Periods

Annual precipitation during the Interim period was considerably

PAN EVAPORATION

MAY 1977 - SEPTEMBER 1977

	MAY	JUNE	JULY	AUGUST	SEPTEMBER	TOTAL
EVP-2	6.820	9.800	7.675	7.260	6.713	38.268 in. (97.201 cm)
EVP-13	4.275	6.375	5.050	4.760	4.113	24.573 in. (62.415 cm)

TABLE 14

WATER BALANCE

SOUTHAM CANYON (ARA-2, EVP-2)
MAY 1977 - SEPTEMBER 1977

AVERAGE PRECIPITATION	TOTAL RUNOFF	ASSUMED SOIL STORAGE CHANGE	TOTAL EVAPO-TRANSPIRATION	PERCENT EVAPO-TRANSPIRATION	PAN EVAPORATION	POTENTIAL EVAPORATION	POTENTIAL EVAPO-TRANSPIRATION	WATER DEFICIT
3.60 in (9.14 cm)	0	0	3.60 in (9.14 cm)	100	38.268 in (97.20 cm)	26.79 in (68.05 cm)	13.4 in (34.04 cm) to 21.4 in (54.36 cm)	9.8 in (24.89 cm) to 17.8 in (45.21 cm)

TABLE 15

less than during the Baseline period. Seasonal distribution of precipitataion was also considerably different from the Baseline period. Precipitation measurements during 1975 and 1976 water years were close to the annual average for the region. The differences in precipitation between the Interim and Baseline periods are due to expected fluctuations above and below average conditions, which is a normal characteristic of annual precipitation. Evaporation measurements at comparable stations during the Interim period are not significantly different from those during the Baseline period. Evaporation from a pan is affected by such meteorological factors as temperature, wind, atmospheric pressure, and relative humidity. Variation of these factors is not likely to cause large variations from year to year in pan evaporation for the entire growing season.

Adequacy of the Existing USGS Precipitation Network to Predict Precipitation Levels on Tract Ua/Ub

The relationship between precipitation at one location and precipitation in the surrounding area tends to have less error involved as longer data bases are used. Adequate predictions of annual and seasonal precipitation on Tract Ua/Ub can probably be made from the USGS precipitation network. This network is on all sides of the project area and has gages at lower and higher elevations than the elevation range in the project area. An attempt to predict precipitation from an individual rainfall event is likely to have considerable error because of the influence of localized storms. Precipitation data to date for the project area have shown that rainfall patterns are influenced by intense isolated storms as well as terrain. Precipitation data for individual storms in isolated areas are important because of its relationship to streamflow, especially on smaller drainages such as Southam Canyon. Therefore, the existing USGS precipitation network is not completely adequate to predict precipitation levels on Tract Ua/Ub.

4.2 AIR RESOURCES

The Interim Air Resources Monitoring Program was designed as a systematic step between the Baseline Monitoring Program and the Development Monitoring Program. The two-year Baseline program was completed by January 1977. At that time the Interim program went into effect. The collection of pertinent air quality and meteorological parameters was continued. During 1977, four monitoring stations were operated with one site (A-6) used for air quality monitoring. Figure 19 shows the locations of the Interim monitoring sites.

The Air Resources Interim Monitoring Program began on January 16, 1977. However, for ease of discussion, the Baseline years referred to in this report are 1975 and 1976 and the Interim year is 1977.

AeroVironment, Inc. is under contract to WRSP for the conducting of the Air Resources monitoring program.

4.2.1 Air Quality Monitoring Program

The Interim Air Quality Program was initiated January 16, 1977. The monitoring equipment at site A-6 was continued in the same fashion as during the Baseline program.

4.2.1.1 Objectives. A prime objective of the program was to determine if the occasional high levels of ozone and non-methane hydrocarbons noted during the Baseline period recur during the Lease Suspension period. Another objective was to maintain continuity of data on other air quality parameters.

4.2.1.2 Methods. Station A-6 (see Figure 19) was operated during the Interim period. Table 16 lists the instruments used and the parameters measured. All parameters, except suspended particulates, are monitored

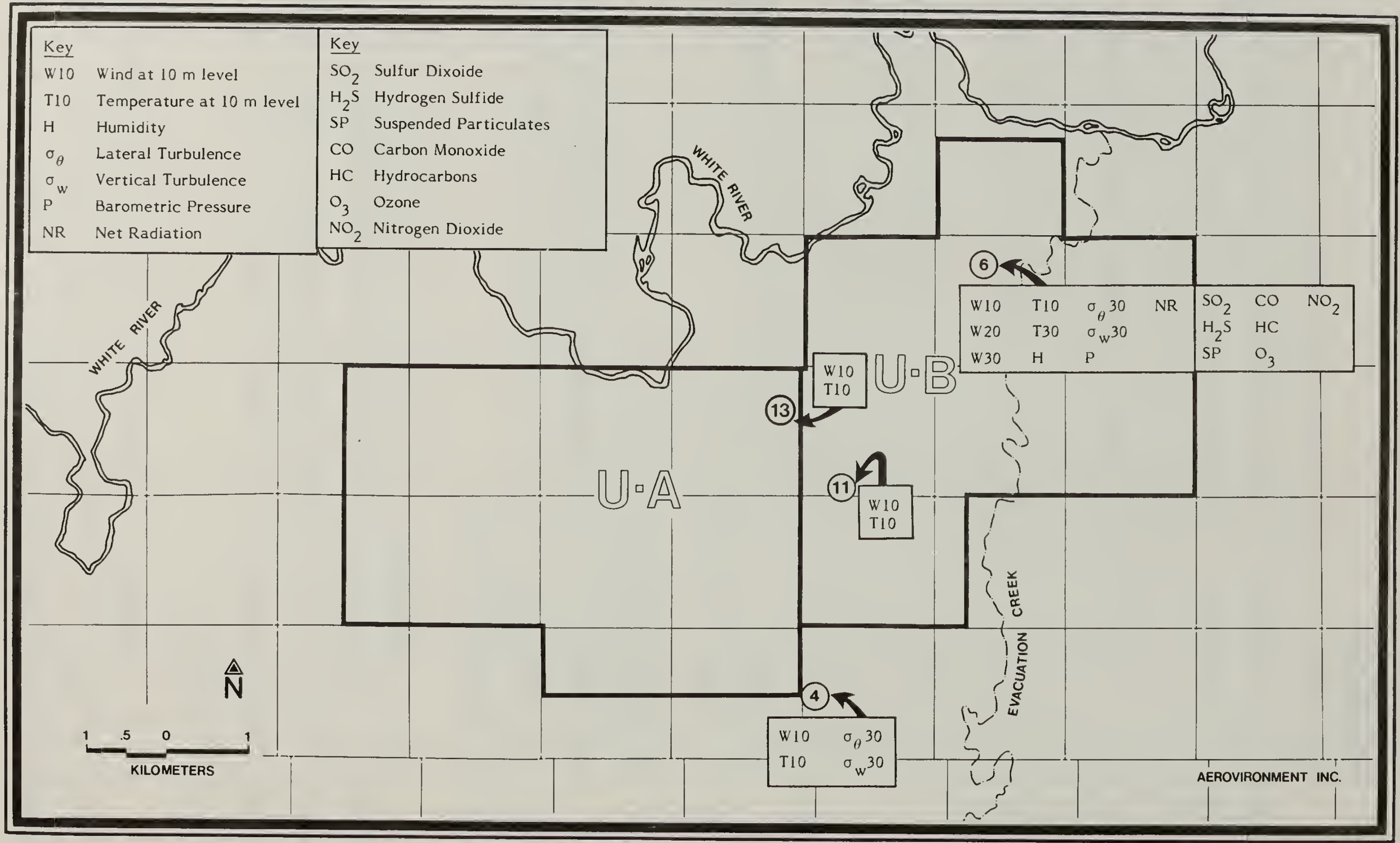


FIGURE 19. Locations of meteorological and air quality measurement stations on Tracts Ua and Ub.

TABLE 16. Air quality monitoring equipment (site A6).

Parameters	Instrument
Suspended Particulates	General Metals Model 5000 HiVol w/Constant Flow Control
Sulfur Dioxide, Hydrogen Sulfide, Total Sulfur	Tracor 270 HA Sulfur Analyzer-Gas Chromatography
Nitrogen Oxides (NO, NO_x, NO_2)	Monitor Labs Model 8440 NO_x Analyzer Chemiluminescence
Hydrocarbons (Total hydrocarbons, CH_4)	Beckman 6800 Gas Chromatograph, Flame Ionization
Carbon Monoxide	Beckman 6800 Gas Chromatograph, Flame Ionization
Oxidants (O_3)	Monitor Labs 8410, Ozone Analyzer, Chemiluminescence

continuously. Data are recorded on digital punch tapes every 6 minutes and on strip charts every 2 minutes.

Station A-3 was maintained on a standby basis. A-3 has the same instrumentation as A-6 and would have been put into service if A-6 had become inoperable. This need never developed.

Suspended particulates are measured over a 24 hour period at A-6 every sixth day. This schedule is the same as used in the Baseline Monitoring Program and is considered sufficient for continued characterization of the randomly produced background particulate material levels. The specific measurement techniques used are the same as those used during the Baseline program, which have been described extensively in previous reports on that program.

Quality assurance is provided through four techniques. First, all of the instruments used during this year were recalibrated on January 11-13, 1977. Second, the air quality equipment is recalibrated (dynamic multiple point) monthly and, third, the equipment receives span and zero checks every two days. This schedule of calibration is more frequent than that for the Baseline program. It reflects the greater reliability demanded of single air monitoring stations. Fourth, in addition to the normal internal quality assurance procedures maintained by AeroVironment, the White River Shale Project is participating voluntarily in an air pollution measurement quality assurance program implemented by the Environmental Protection Agency.

4.2.1.3 Present Status and Plans for 1978

The extent of the data collected during 1977 is tabulated in Table 17. This table lists the percentage of hours during this period

TABLE 17. Percentage of time monitoring was performed for air quality parameters during 1 January - 31 December 1977.

Component	# of Stations	Percentage
SO_2	1	94
H_2S	1	94
Total HC	1	97
NO_x	1	96
O_3	1	96
CO	1	97
Suspended Particulates	1	97

that data collection was underway for each parameter. Calibration time is counted as data collection time.

The plans for 1978 are to continue with data collection operations just as during 1977. The only change envisioned at this time is to stop reporting non-methane hydrocarbon data since regulatory agencies are questioning the accuracy of the state-of-the-art equipment available for such monitoring.

4.2.1.4 Data Summary:

Gaseous Pollutants

Both gaseous and particulate air quality measurements were made at station A-6. There are no Utah State air quality standards for gaseous pollutants, while Federal standards exist for all components except H_2S. For reference in the ensuing discussions, Table 18 presents the Federal Ambient Air Quality Standards (AAQS) for the various gaseous pollutants monitored on the tract. For H_2S, a reference for interpreting the data is the California 1-hour standard of 42 $\mu g/m^3$(.03 ppm).

The air quality continued to be consistently very good on the tract. During this study period, except for sporadic occurrences of high non-methane hydrocarbon (NMHC), the air on the tract was very clean with respect to gaseous pollutants. The only other pollutant that was present in measurable quantities was ozone, which has a natural non-zero background level. Otherwise almost all instruments measuring gaseous pollutants were recording at their threshold limit most of the time, the same as during the Baseline period.

Comparisons are made with the Baseline monitoring data to determine any significant changes in results. Generally, the data do not exhibit any

TABLE 18 Federal air quality standards for gaseous pollutants.

Pollutant	Averaging Time	Primary Standards	Secondary Standards
Ozone (O_3)	1 hour	160 $\mu g/m^3$ (0.08 ppm)	Same as primary
Carbon Monoxide CO	8 hours	10 mg/m^3 (9 ppm)	Same as primary
	1 hour	40 mg/m^3 (35 ppm)	Same as primary
Sulfur Dioxide SO_2	Annual Average	80 $\mu g/m^3$ (0.03 ppm)	-
	24 hour	365 $\mu g/m^3$ (0.14 ppm)	-
	3 hour	-	1300 Ug/m^3 (0.5 ppm)
Nitrogen Dioxide NO_2	Annual Average	100 $\mu g/m^3$ (0.05 ppm)	Same as primary
Hydrocarbons (corrected for methane - NMHC)	3 hour (6-9 a.m.)	160 $\mu g/m^3$ (0.24 ppm)	Same as primary

significant abnormalities from the Baseline data. Specific comments are included with the discussion of each parameter when appropriate.

1. Ozone (O_3)

Plots of diurnal variations of O_3 at site A-6 for January, April, July and October 1977 are presented in Figures 20 through 23. The months of January (winter), April (spring), July (summer) and October (fall) are presented as representation of each season. The average diurnal trend consists of low readings of about 40 $\mu g/m^3$ in the early morning hours and high values in the afternoon hours.

The mean Baseline hourly values are also shown. The average value of the Interim period was 5 - 15 $\mu g/m^3$ less than the average Baseline ozone for the winter, spring and fall months but was a little more during October. The nominal detection limit for the ozone analyzer is 2 $\mu g/m^3$. Since the instrument's precision is $\pm$ 10 $\mu g/m^3$, the difference between the Baseline and Interim periods does not appear to be significant.

The peak hour, second highest hour, average seasonal values and number of exceedances are tabulated in Table 19. The highest hourly and second highest hourly values during the Interim period were 160 $\mu g/m^3$, which is the national standard. The average values by seasons of the year ranged between 50 and 70 $\mu g/m^3$ which fall around the middle of the typical global background value.

The prevailing wind directions over the tract during high readings were southwest if the occurrences were during daytime and southeast if the occurrences were during the nighttime. The following is a discussion of instances of ozone value $\geq$100 $\mu g/m^3$ and possible explanations of such high readings.

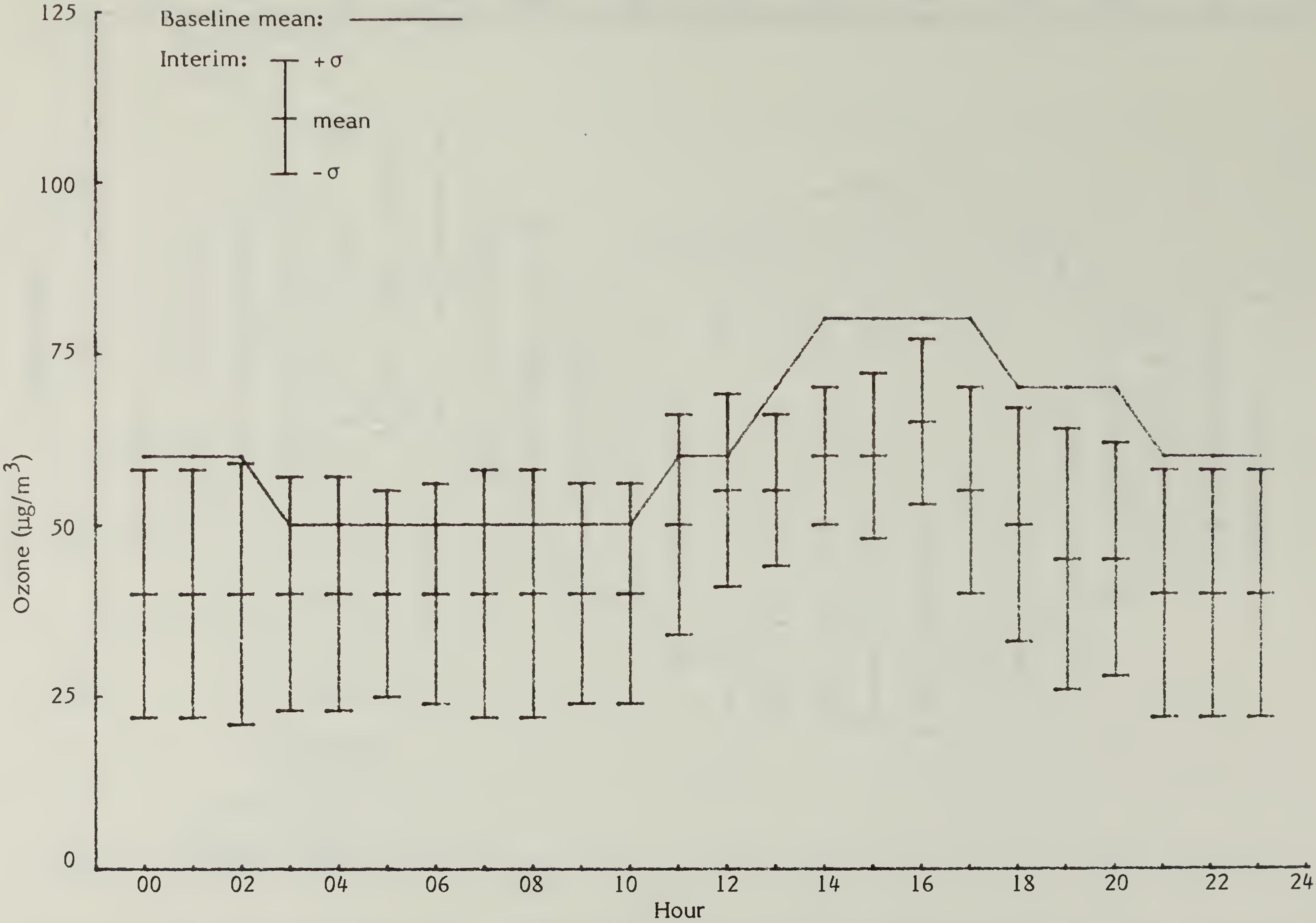


FIGURE 20. Diurnal variation in mean ozone concentrations with their standard deviations during the Interim Period compared with the baseline mean values at site A6 during January.

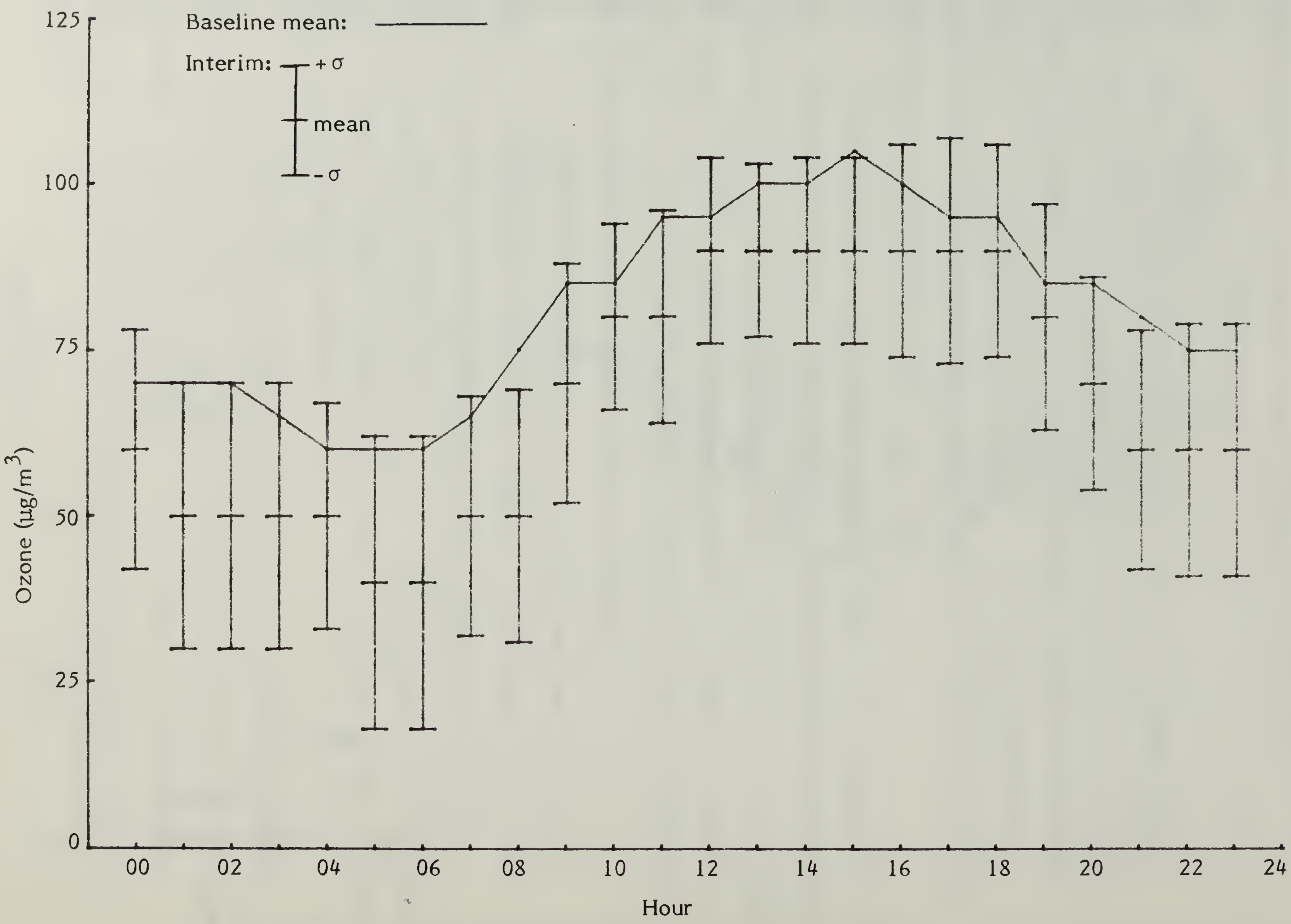


FIGURE 21. Diurnal variation in mean ozone concentrations with their standard deviations during the Interim Period compared with the baseline mean values at site A6 during April.

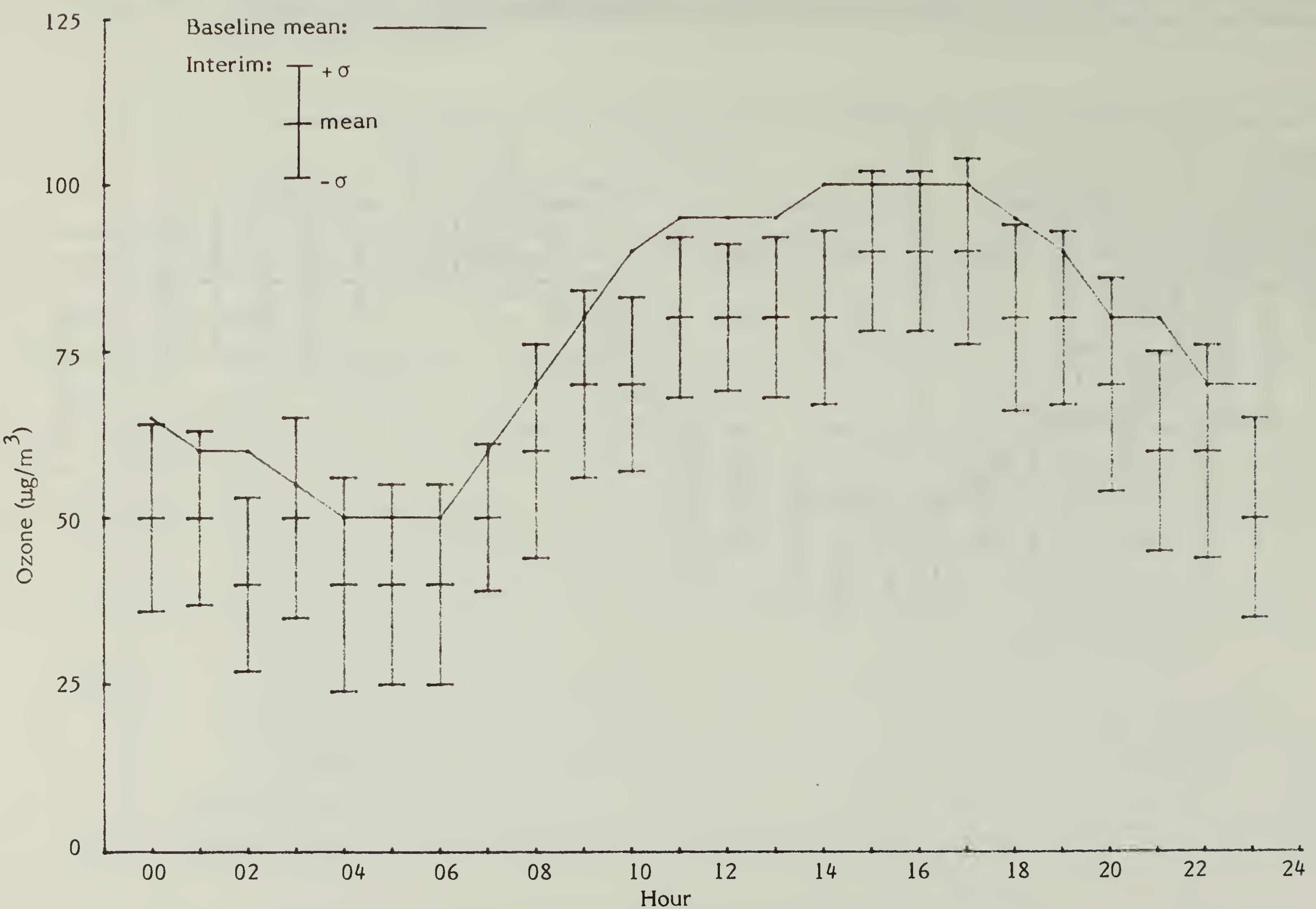


FIGURE 22. Diurnal variation in mean ozone concentrations with their standard deviations during the Interim Period compared with the baseline mean values at site A6 during July.

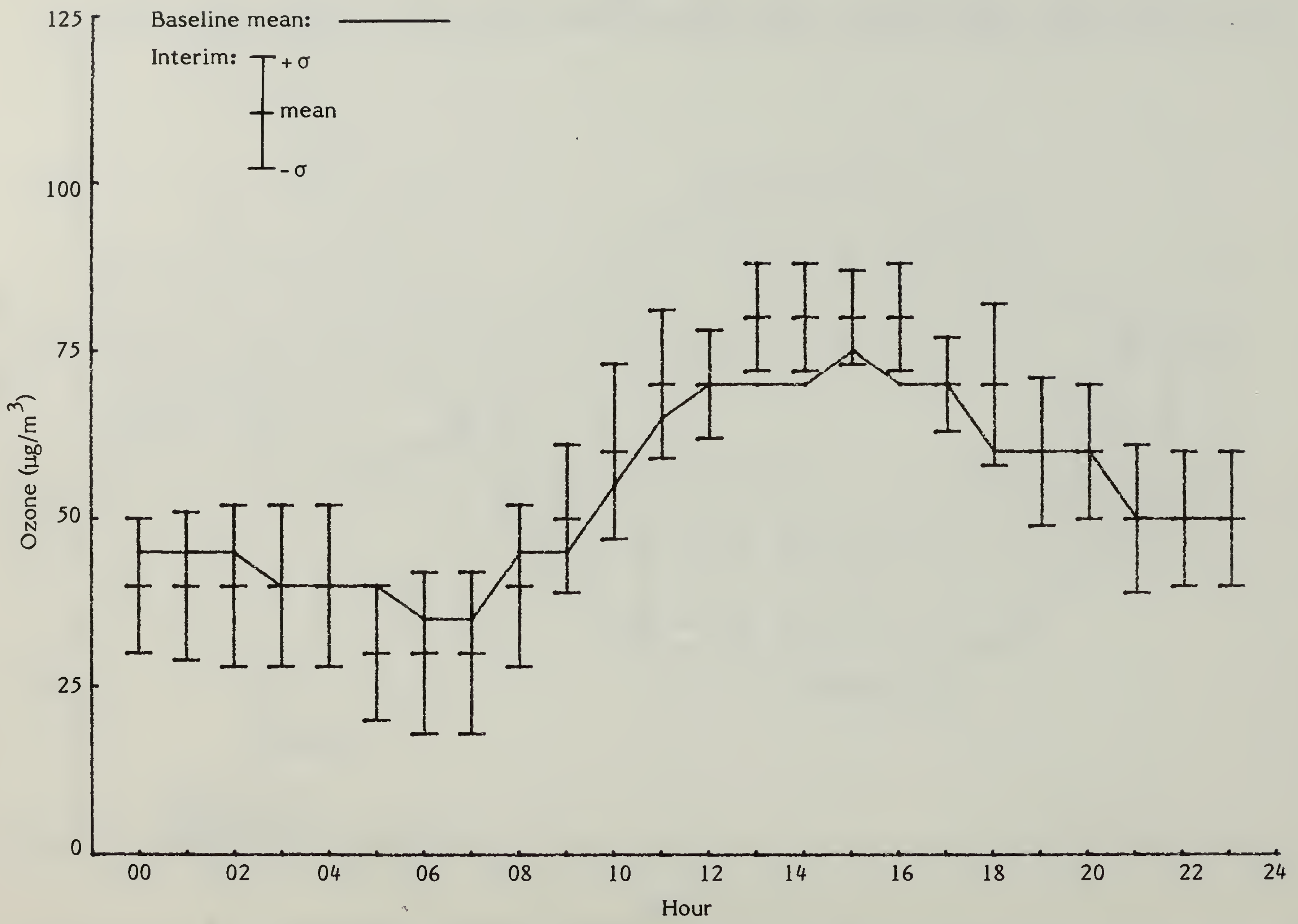


FIGURE 23. Diurnal variation in mean ozone concentrations with their standard deviations during the Interim Period compared with the baseline mean values at site A6 during October.

TABLE 19. Comparison of the highest, second highest and average 1-hour O_3 readings (in $\mu g/m^3$) as well as the percent of observations exceeding the standard (160 $\mu g/m^3$) at site A6 from the Baseline Period (1975-1976) and the Interim Period (1977).

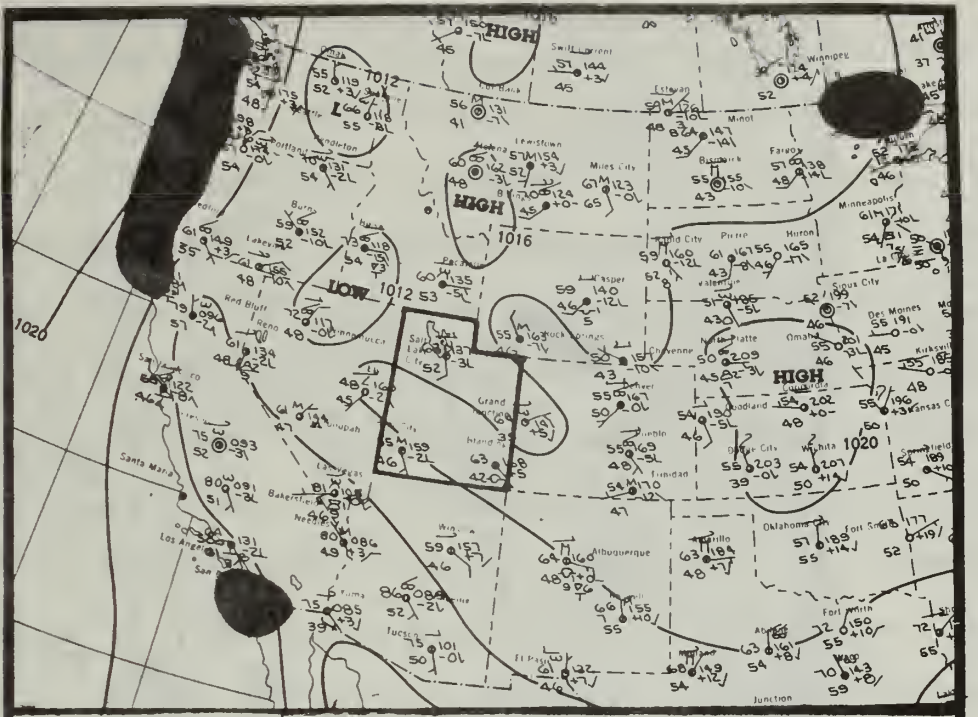
	Peak Concentration		Second Highest Concentration		Average		No. of Observations		Number of Exceedances of Standard	
Season	Baseline	Interim	Baseline	Interim	Baseline	Interim	Baseline	Interim	Baseline	Interim
Winter	150	100	150	100	70	50	2,872	2,124	0	0
Spring	150	160	140	160	75	70	4,033	2,008	0	0
Summer	140	160	140	160	75	70	4,135	2,046	0	0
Fall	140	100	130	100	55	55	4,244	2,004	0	0

Episode of Ozone Transport - The June 7-8, 1977 period saw readings as high as the standard (160 μg/m^3). For over a week prior to this a strong high pressure area had affected the entire Western United States. Figure 24 shows the synoptic pattern at 0500 MST, June 7, 1977. The flow aloft was light southwesternly. The center of the western ridge aloft is just to the east of Utah. The surface map, however, is more confused because of centers of summer thermal lows interspersed with high centers.

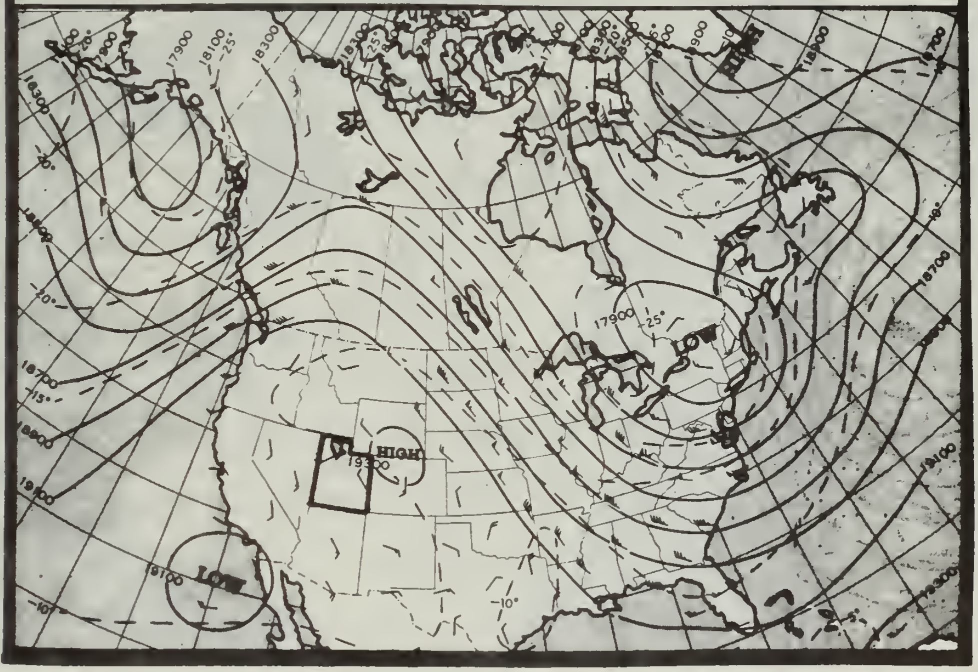
Vukovich (1977) states that high ozone occurs most often on the backside of the high pressure system in air that has had large residence times in that system. Large concentrations of ozone precursors occur when an air mass passes over heavily populated areas. Shortly after the system moved in from the Pacific Ocean, second stage alerts were issued on June 1 and 2 in the Los Angeles area. The air mass remained long enough to become generally polluted.

The peak values occurred in the evening after the sun had set (1900, June 7, and 0000, June 8, MST). This is after the normal locally-induced photochemical time has passed. Northwestern Colorado also reported values in excess of 120 μg/m^3 during this episode.

Locally Induced Ozone Episode - Stasnick (1974) mentions that high rural ozone levels could be due to naturally occurring precursors, especially during slow-moving or quasi-stationary anticyclones. On May 12, 1977 an episode occurred with readings of 160 μg/m^3 between 1000 - 1500 hours, exactly during the highest solar radiation period. Figure 25 shows the general synoptic pattern at 0500 MST, May 12. This was a transition period with light surface air flows over Utah at this time.

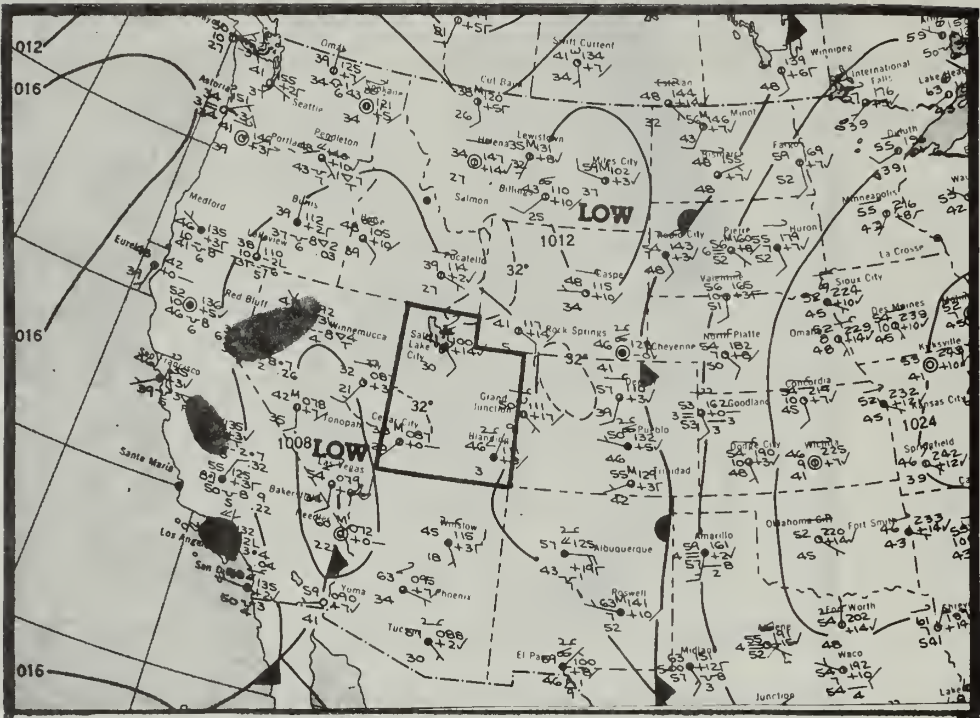


Surface Map

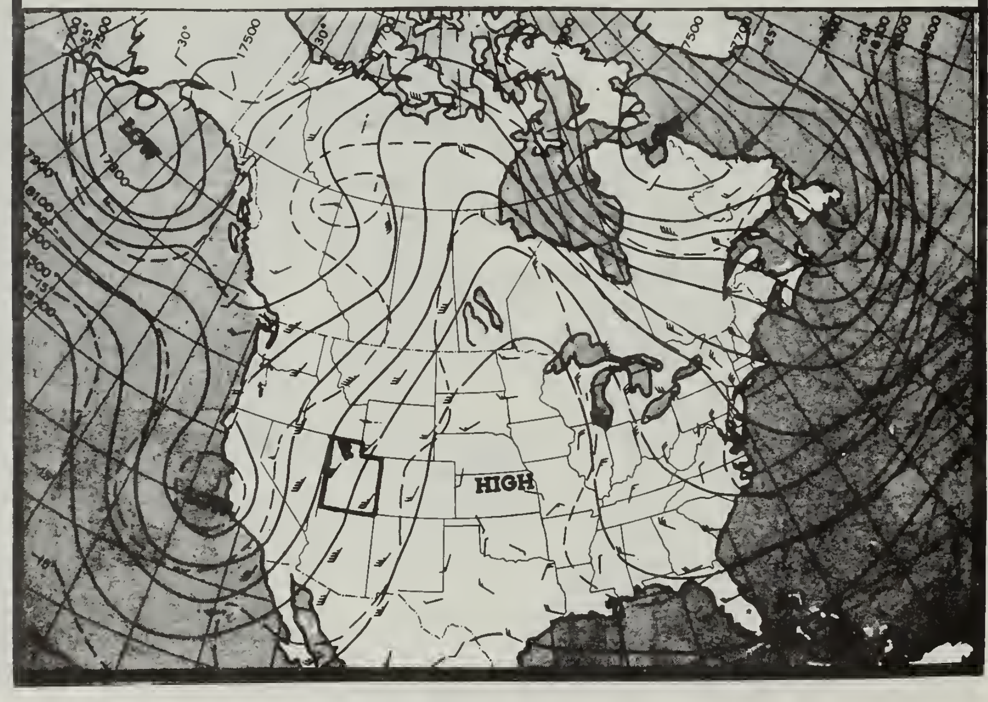


500 MB Level

FIGURE 24. Synoptic situation at 0500 MST, 7 June 1977.



Surface Map



500 MB Level

FIGURE 25. Synoptic situation at 0500 MST, 12 May 1977.

Stratospheric Intrusion of Ozone - There are several incidents of increases in ozone during nighttime hours. A perusal of the synoptic maps during the last three years gives the passages of low pressure and frontal systems through the area. The number of passages by month for 1975, 1976 and 1977 are listed in Table 20. Along with each monthly total, the number with readings of ozone ≥100 μg/m^3 during nighttime hours are tabulated. There are some stratospheric intrusions during most forontal passages but only a few manage to affect the surface. Several instances have occurred where the ozone readings jump as much as 30 to 40 μg/m^3. This seems to occur the hour after the barometric pressure reaches its minimum. The most vertical transfer between the troposphere and stratosphere occurs just on the cold side of the front (Staley, 1960). Increases in ozone seem to be more pronounced when the system is deepening. None of these incidents reached the air quality standard. Incidents such as these are noted only in rural areas since low readings, such as are discussed here, are lost in the higher values observed in the urban environment. A reading as high as 450 μg/m^3 has been observed during a frontal passage and is attributed to stratospheric intrusion (Lamp, 1977).

Figure 26 shows a typical meteorological case where the ozone reaches a peak of 130 μg/m^3 at 0500 and 0600 MST along with a frontal passage. The hourly ozone readings remained above 100 μg/m^3 from 0300 through 2100 MST of that day. The average was 100 μg/m^3. Actually, the low center stagnated near the area and deepened.

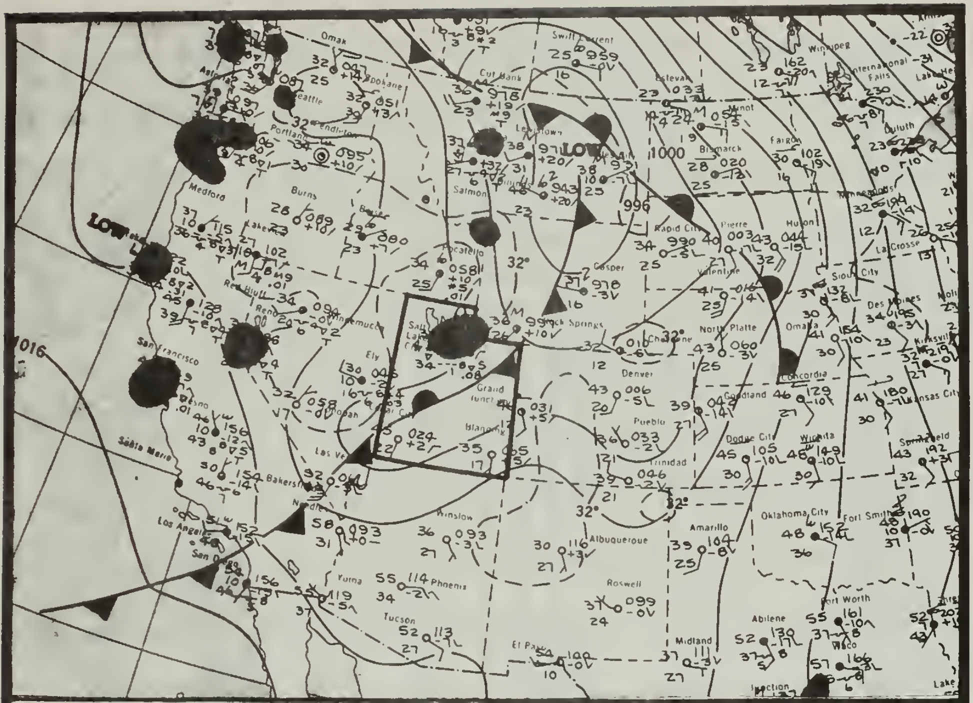
2. NMHC, Non-Methane Hydrocarbons

Table 21 presents the statistics on 6 A.M. to 9 A.M. readings at station A-6. The highest and second highest values have occurred during

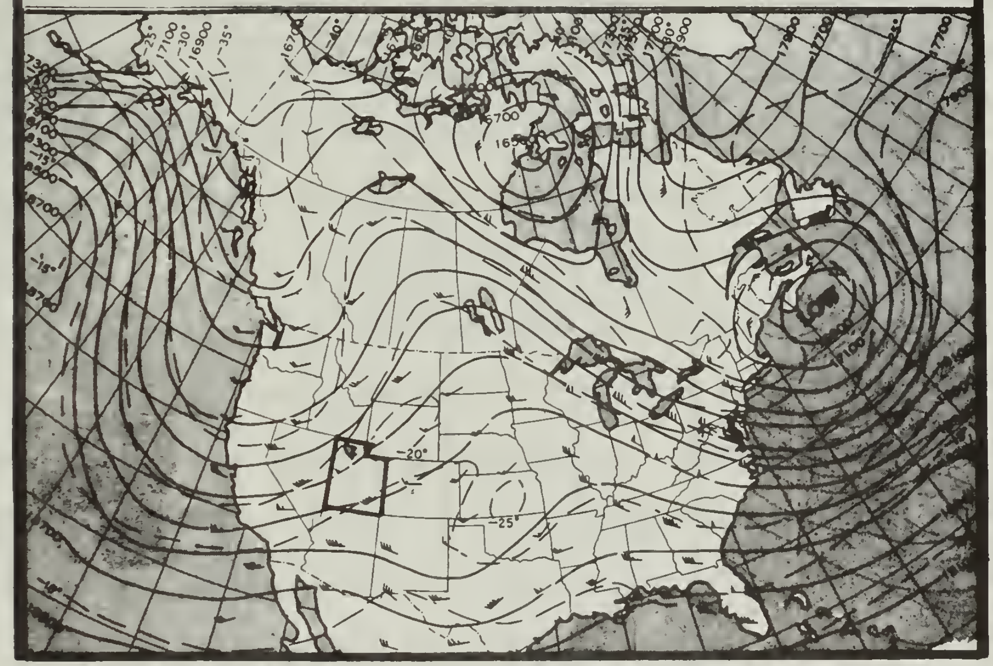
TABLE 20. Number of cases by month of frontal passages/and those with readings of ozone $\geq 100\ \mu g/m^3$ during nighttime hours at site A6.

		Month												
		J	F	M	A	M	J	J	A	S	O	N	D	Annual
Baseline	1975	8/1*	6/3	7/4	5/3	6/2	6/1	4/1	5/1	3/1	5/0	5/0	4/0	57/17
	1976	2/0	6/0	6/2	7/1	5/1	6/1	4/3	4/0	3/0	2/0	1/0	3/1	49/9
Interim	1977	2/1	5/0	6/2	6/2	7/3	5/2	6/1	3/2	4/0	5/0	7/0	4/0	60/13
Totals		12/2	17/3	19/6	18/6	18/6	17/4	14/5	12/3	10/1	12/0	13/0	11/1	166/41

*Site A3 – no data at site A6



Surface Map



500 MB Level

FIGURE 26. Synoptic situation at 0500 MST, 24 March 1977.

TABLE 21. Comparison of the highest, second highest and average 3-hour (6-9 A.M.) NMHC reading (in μg/m^3), as well as the percent of observations exceeding the standard (160 μg/m^3) at site A6 during the Baseline Period (1975, 1976) and Interim Period (1977).

Season	Peak Concentration		Second Highest Concentration		Average		No. of Observations		Number of Exceedances of Standard	
	Baseline	Interim	Baseline	Interim	Baseline	Interim	Baseline	Interim	Baseline	Interim
Winter	1,217	297	1,083	193	254	47	87	89	38	4
Spring	1,403	1,800	930	1,597	185	76	169	92	40	8
Summer	1,037	170	927	147	124	48	96	79	15	1
Fall	430	1,367	400	1,010	62	105	140	89	10	13

the Interim period, 1800 $\mu g/m^3$ and 1,597 $\mu g/m^3$, respectively, almost 11 times higher than the 3-hour 6-9 A.M. Federal standard of 160 $\mu g/m^3$. However, out of a total of 349 observations, there were only 7.5 percent of exceedances during the Interim period compared to 20 percent of exceedances out of 492 observations during the two year Baseline program.

Some sporadic high readings of NMHC could have resulted from numerous activities on the tract, expecially at the beginning of the Baseline period. Also, local plant life can emit terpene oils and gases. Halligan (1975) supports the contention that terpenes are naturally emitted from sagebrush. The amount and composition of the terpene oil changes according to seasonal patterns. The surrounding soil and litter also contain many of the same volatile substances. He found a greater amount emitted during summer and fall and lesser during winter and spring. Rasmussen (1972) figures there is a 6.2-fold greater emission level from natural sources than from man-made sources.

The precision of the Beckman gas chromatograph for the analysis of hydrocarbons is 0.1 ppm ($\sim$ 70 $\mu g/m^3$) for THC (total hydrocarbons) and 0.1 ppm for CH_4 (methane). To obtain NMHC, the CH_4 reading is subtracted from the THC reading. This compounds the error to about 0.2 ppm (130 $\mu g/m^3$), and considerably larger errors are possible on a sample-to-sample basis. Since the NMHC standard 160 $\mu g/m^3$, the instrumentation precision is inconsistent with the standard, even if perfectly calibrated. However, the EPA prescribed reference method for measuring non-methane hydrocarbons is by flame ionization detection and gas chromatography, exactly as used in the Beckman instrument, and the measurement procedures used during the program are the best available. This inconsistency between the ambient air quality standard and the instrumentation technique is recognized by the EPA.

From the perspective of the Baseline Monitoring Program, the significance of the occasional large NMHC values observed should not be overemphasized, both because of this instrumentation inadequacy as well as the irrelevance of the NMHC standard for rural areas.

3. Carbon Monoxide, CO

Table 22 presents the highest, second highest and average 1-hour and 8-hour CO concentration at site A-6. The maximum 1-hour and 8-hour readings during the interim period were 1.0 and 0.6 mg/m^3, which were lower than the 3.0 and 1.8 mg/m^3 recorded during the baseline period. However, all values were well below the national standards of 40 mg/m^3 (1-hour) and 10 mg/m^3 (8-hour).

Contamination of CO readings by generator exhaust was a problem during the first part of the Baseline period. The normal background level is 0.5 mg/m^3 and practically all of the readings fall around and below this value.

No diurnal or seasonal variations were observed in the CO levels. Readings were generally near the detection limit of the instrument, 0.1 mg/m^3 (0.1 ppm).

4. Nitrogen Dioxide, NO_2

Of the nitrogen oxides, only NO_2 has a Federal ambient air quality standard (annual average of 100 μg/m^3). Table 23 shows the annual averages for both the Baseline and Interim periods. The California standard (for reference) is a 1-hour average of 470 μg/m^3. This table also shows the highest, second highest and average of 1-hour averages. Again, activity on the tract during the first part of the Baseline program could have produced the highest values of 100 μg/m^3.

TABLE 22. Comparisons of the peak, second highest, and average 1-hour and 8-hour moving mean CO readings (in mg/m^3), as well as the number of observations exceeding the standard (40 mg/m^3, 1-hour) (10 mg/m^3, 8-hour) at site A6 for the Baseline Period (1975, 1976) and the Interim Period (1977).

		Peak Concentration		Second Highest Concentration		Average		No. of Observations		Number of Exceedances of Standard	
Season	Averaging Time	Baseline	Interim	Baseline	Interim	Baseline	Interim	Baseline	Interim	Baseline	Interim
Winter	1-hour	3.0	1.0	2.2	0.9	0.3	0.2	3,336	2,112	0	0
	8-hour	0.6	0.6	0.5	0.5	0.2	0.2			0	0
Spring	1-hour	0.8	0.6	0.7	0.6	0.1	0.2	3,329	2,160	0	0
	8-hour	0.3	0.6	0.3	0.6	0.1	0.2			0	0
Summer	1-hour	3.0	0.9	2.7	0.6	0.2	0.1	2,038	1,920	0	0
	8-hour	1.8	0.5	1.7	0.5	0.1	0.1			0	0
Fall	1-hour	1.2	0.4	1.2	0.3	0.2	0.2	3,545	2,136	0	0
	8-hour	0.3	0.3	0.3	0.3	0.1	0.2			0	0

TABLE 23. The peak, second highest and average hourly-averaged NO_2 concentrations ($\mu g/m^3$) as well as the number of observations exceeding the 1-hour standard (470 $\mu g/m^3$) at site A6 from the Baseline Period (1975,1976) and the Interim Period (1977).

	Peak Concentration		Second Highest Concentration		Average		No. of Observations		Number of Exceedances of Standard	
Season	Baseline	Interim	Baseline	Interim	Baseline	Interim	Baseline	Interim	Baseline	Interim
Winter	20	10	20	10	5	0	2,460	2,112	0	0
Spring	20	0	20	0	5	0	3,984	1,344	0	0
Summer	100	10	90	10	15	0	3,600	2,136	0	0
Fall	100	10	80	10	10	0	3,996	2,136	0	0
Annual	-	-	-	-	0	0	2	1	0	0

The precision of the instrument is around 20 $\mu g/m^3$ and readings are generally below this value and near the lower detection limit of this instrument (5 $\mu g/m^3$). No seasonal trends are evident.

5. Sulfur Dioxide, SO_2

Table 24 gives the Baseline and Interim periods comparison of the highest, second highest, average and percent exceedance of both the 3-hour and 24-hour readings.

No seasonal or diurnal trend has been evident and most values are near the detection limit of 10 $\mu g/m^3$ (8 ppb). The highest 3-hour SO_2 reading of 15 $\mu g/m^3$ was recorded in the fall of 1977. The standard for a 3-hour averaging time is 1,300 $\mu g/m^3$. The highest 24-hour SO_2 reading was 10 $\mu g/m^3$ and was also recorded in the fall of 1977. Again, this reading is well below the 24-hour standard of 365 $\mu g/m^3$. The annual average on the tract is close to 0 $\mu g/m^3$ as compared to the annual standard of 80 $\mu g/m^3$. Most values have been near the detection limit of the instrument ($<$20 $\mu g/m^3$).

6. Hydrogen Sulfide, H_2S

Since there are no Federal standards for H_2S, a reference for interpreting the data is the California 1-hour standard of 42 $\mu g/m^3$ (0.03 ppm).

Most readings are below the detection limit (10 $\mu g/m^3$ or .008 ppb) of the instrument. Table 25 gives the comparisons of the Baseline and Interim periods with highest, second highest, average and percent of exceedances. Some values during the initial time of the Baseline period were higher and probably locally-induced by tract activity.

TABLE 24. The peak, second highest and average hourly averaged SO_2 concentrations ($\mu g/m^3$) as well as the number of observations exceeding the 3-hour standard (1300 $\mu g/m^3$) and the 24-hour standard (365 $\mu g/m^3$) at site A6 during the Baseline Period (1975,1976) and Interim Period (1977).

Season	Averaging Time	Peak Concentration		Second Highest Concentration		Average		No. of Observations		Number of Exceedances of Standard	
		Baseline	Interim	Baseline	Interim	Baseline	Interim	Baseline	Interim	Baseline	Interim
Winter	3-hour	10	5	5	5	3	0	1,144	704	0	0
	24-hour	5	0	5	0	3	0	143	88	0	0
Spring	3-hour	10	5	10	5	3	0	1,216	712	0	0
	24-hour	5	0	5	0	3	0	152	89	0	0
Summer	3-hour	10	10	10	10	4	2	1,136	688	0	0
	24-hour	5	5	5	5	3	2	142	86	0	0
Fall	3-hour	5	15	5	10	3	3	1,376	488	0	0
	24-hour	5	10	5	5	3	3	172	61	0	0
	Annual	-	-	-	-	5	0	2	1	0	0

TABLE 25. The peak, second highest and average hourly-averaged H_2S concentrations ($\mu g/m^3$) as well as the number of observations exceeding 42 $\mu g/m^3$ at site A6 from the Baseline Period (1975,1976) and the Interim Period (1977).

	Peak Concentration		Second Highest Concentration		Average		No. of Observations		Number of Exceedance 42 $\mu g/m^3$	
Season	Baseline	Interim	Baseline	Interim	Baseline	Interim	Baseline	Interim	Baseline	Interim
Winter	20	5	20	0	5	0	1,320	2,098	0	0
Spring	30	5	30	5	10	0	1,680	2,146	0	0
Summer	20	5	15	5	5	0	1,440	2,088	0	0
Fall	5	5	0	5	0	0	2,040	1,536	0	0

No diurnal or seasonal trends were evident. The highest value of 30 μg/m^3 was recorded during the beginning of the Baseline period when tract activity was high. The highest hourly value during the Iterim period was 5 μg/m^3.

Suspended Particulate, TSP

Particulate concentrations are monitored by means of high volume samplers which sample over a period of 24 hours once every six days. The size of the particulate matter collected by the samplers ranges from below 1 μm to somewhat above 25 μm.

Table 26 gives the geometric mean, standard geometric deviation, maximum and minimum of the total suspended particulate concentrations in μg/m^3 at site A-6. The Baseline and Interim periods are shown by season.

The geometric mean presented can be considered to correspond to the maximum concentration to be expected at a 50% frequency because particulate concentrations have been found to be generally log-normally distributed. The geometric mean of particulate concentrations during the Interim period ranged from 13.2 μg/m^3 during the winter months to 27.6 ug/m^3 during the summer.

None of the recorded values exceeded Federal or State standards, which are presented in Table 27. The most stringent short-term standard is the National Secondary Standard, which sets the upper limit at 150 μg/m^3, averaged over 24 hours; this is not to be exceeded more than once a year.

4.2.2 Meteorological Monitoring Program

Meteorological data collection in the Interim Monitoring Program was implemented January 16, 1977. Monitoring equipment at the 4 sites are identical to those used during the 2-year Baseline period.

TABLE 26. Geometric means, standard geometric deviations, and maximum and minimum of particulate concentrations for Baseline Period (1975, 1976) and Interim Period (1977) at site A6.

	Season	Baseline	Interim
Geometric Mean	Winter Spring Summer Fall	14.2* 17.2 37.0 27.2	13.2 22.2 27.6 22.9
Standard Geometric Deviation	Winter Spring Summer Fall	2.6* 1.9 1.4 2.0	1.5 1.8 1.5 1.7
Maximum	Winter Spring Summer Fall	51.9* 52.0 74.7 101.2	32.6 58.3 47.2 51.4
Minimum	Winter Spring Summer Fall	3.5* 4.9 18.7 4.9	5.6 7.6 13.2 9.7
Geometric Mean	Annual	32.5	22.2
Standard Geometric Deviation	Annual	2.2	1.8

* 1976 only, insufficient data for 1975.

TABLE 27. Ambient air quality standards for particulate matter ($\mu g/m^3$).

Pollutant	Averaging Time	Utah Standards	National Standards	
			Primary	Secondary
Suspended Particulate Matter	Annual Geometric Mean	90	75	60
	24 hour	200	260	150

4.2.2.1 Objectives. The objectives of continuing meteorological measurements in the Interim Monitoring Program were to extend the meteorological data base, determine trends, extend data collection at site A-13 to a full year, and to provide data verification of baseline data for use in future air pollutant dispersion modeling work.

4.2.2.2 Methods. The meteorological parameters monitored are shown in Table 28. Meteorological data are collected continuously and recorded on digital punch tapes every 6 minutes. Strip charts are also used at sites A-4 and A-6 for a backup record.

Table 29 lists the meteorological monitoring equipment used.

4.2.2.3 Present Status & Plans for 1978. The extent of the data collected during 1977 is tabulated in Table 30. This table lists the percentage of hours during this period that data collection was underway for each parameter. No changes in monitoring programs are planned for 1978.

4.2.2.4 Data Summary. The year 1977 was dry in the western part of the United States. The blocking pattern of high pressure off the Pacific coast during the winter of 1976-1977 shunted the storm tracks further north than usual and precipitation was much less than normal, especially during the critical period when winter precipitation should have been at its peak. Temperatures for the winter were above normal.

The spring and summer were also drier than normal with slightly higher than normal temperatures. June was one of the hottest on record. By mid-September, Grand Junction had recorded the driest 12-month period on record.

TABLE 28. Meteorological parameters monitored during the lease suspension period.

Parameter	Station A4	Station A6	Station A11	Station A13
Meteorology				
WS/WD - 10 m	X	X	X	X
WS/WD - 20 m		X		
WS/WD - 30 m		X		
T - 10 m	X	X	X	X
Δ T - 10-30 m		X		
σ_θ - 10 m	X			
σ_θ - 30 m		X		
σ_w - 10 m	X			
σ_w - 30 m		X		
Net Solar Radiation		X		
Dew Point		X		
Relative Humidity		X		
Barometric Pressure		X		

TABLE 29. Meteorological monitoring equipment.

Parameters	Instrument	Location
Wind Speed and Direction	MRI Model 1022 Anemometer	A-6 (10, 20 & 30m) A-4 (10 m)
Wind Speed, Direction, and Temperature	MRI Model 1071 Mechanical Weather Station	A-11 (10m) A-13 (10m)
Wind Variance	MRI Model 1022 and R.M. Young anemometer, and AeroVironment Sigma Meter	A-6 (10 & 30m) A-4 (10m)
Temperature and Lapse Rate	MRI Thermistors w/R.M. Young Shield	A-6 (10 & 30m) A-4 (10 m)
Dew Point	Weather measures model H321S Hydrograph	A-6

TABLE 30. Percentage of time monitoring was performed for meteorological parameters during 1 January - 31 December 1977.

Component	# of Stations	Percentage
Wind (10m)	4	100
Wind (20m)	1	100
Wind (30m)	1	100
Temp. (10m)	4	100
Temp. (30-10m)	1	100
Rel. Hum. (10m)	1	99

The fall season saw a continuation of the drought with normal temperatures. October was very dry, but November saw a good snowstorm on tract. Dryness continued into December but a series of late month storms began to help alleviate the moisture situation.

The Interim Program data is presented below and compared quantitatively with the Baseline Program data to determine any significant changes.

Surface Flow

The rugged terrain features in the area complicated the airflow pattern. Table 31 shows the prevailing direction and speed by month for the 4 wind sites. Spatial variation in wind speed on the tract was observed through the Baseline period. Generally, nighttime drainage flow is prevalent throughout the year. Figure 27 shows the typical airflow streamlines for the early morning drainage pattern. The solid arrows on this figure are wind vectors at the monitoring sites, and the longer lines are estimated flow streamlines. Although the month of October 1977 is shown, there was no significant deviation throughout the year in the drainage pattern. This figure was prepared from the wind observations at the 4 wind sites plus knowledge of the wind flow pattern as presented in reports prepared for the Baseline period. The drainage flow is always from higher to lower terrain, as noted during the Baseline period.

Figures 28 and 29 present afternoon streamlines for the two opposite seasons; winter (January 1977) and Summer (July 1977). Very little directional difference was noted except the average speeds are higher during the summer. No significant difference from the Baseline period was noted.

TABLE 31. Prevailing directions and speeds (m/s) on the tracts during the Lease Suspension Period.

Month	Site			
	A4	A6	A11	A13
Jan	W/2.2	ESE/2.0	SE/2.2	SE/1.3
Feb	W/2.7	ESE/2.9	SE/2.9	W/1.8
Mar	W/3.6	ESE/3.6	SE/3/6	W/2.7
Apr	SE/2.9	ESE/2.9	SE/2.9	SE/2.2
May	S/3.8	SE/4.0	SSE/4.0	S/3.4
Jun	W/3.8	ESE/3.8	SE/3.8	WNW/3.1
Jul	W/3.4	ESE/3.1	SE/3.4	SE/2.7
Aug	WNW/3.1	ESE/3.4	SE/3.4	SE/2.7
Sep	WNW/3.6	ESE/3.4	SE/3.6	SE/2.7
Oct	SE/2.7	ESE/2.7	SE/2.9	SE/2.0
Nov	W/2.7	ESE/2.5	SE/2.7	Var/2.0
Dec	W/3.4	ESE/2.9	WNW/2.9	ESE/2.0
Annual	W/3.2	ESE/3.1	SE/3.2	SE/2.4

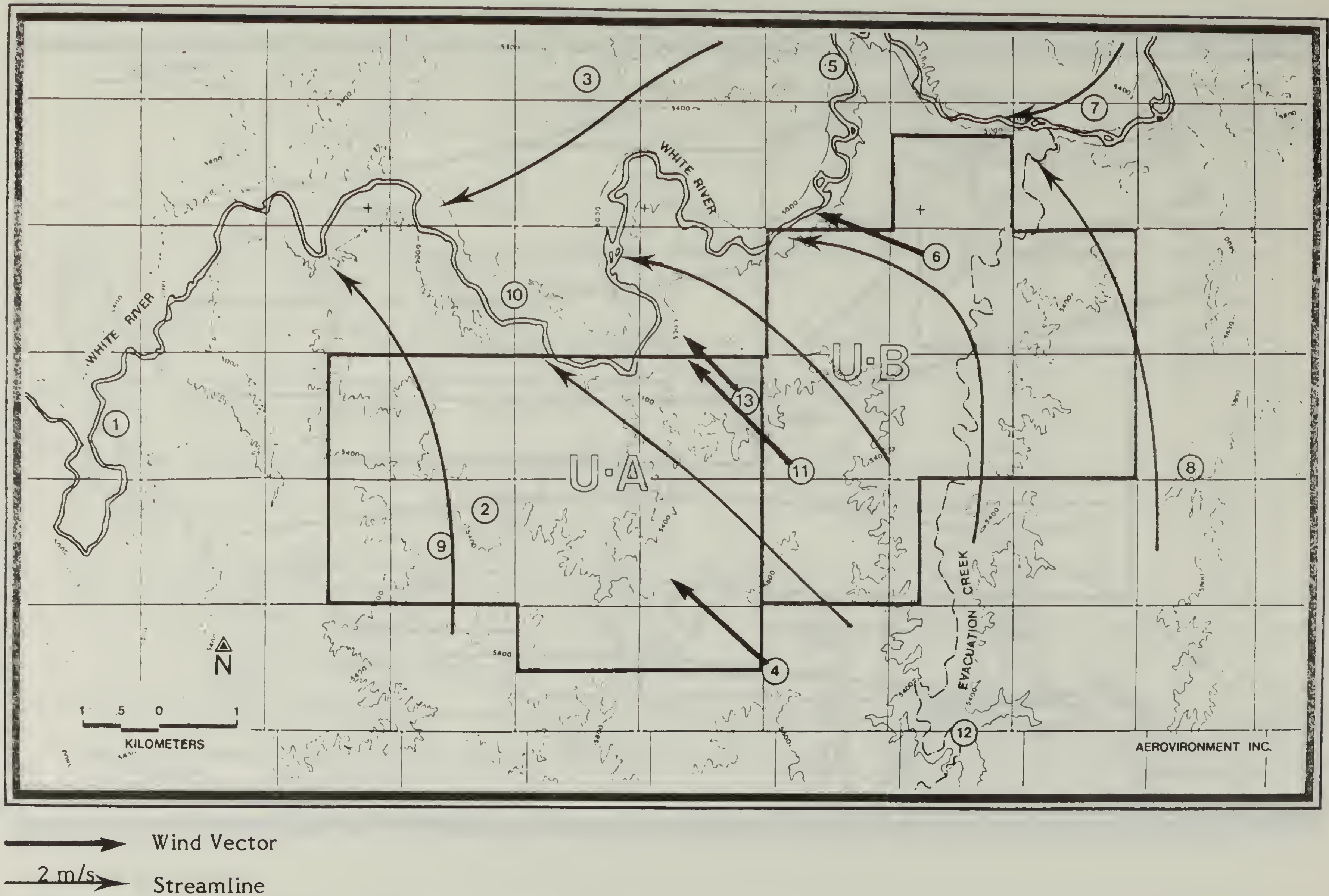
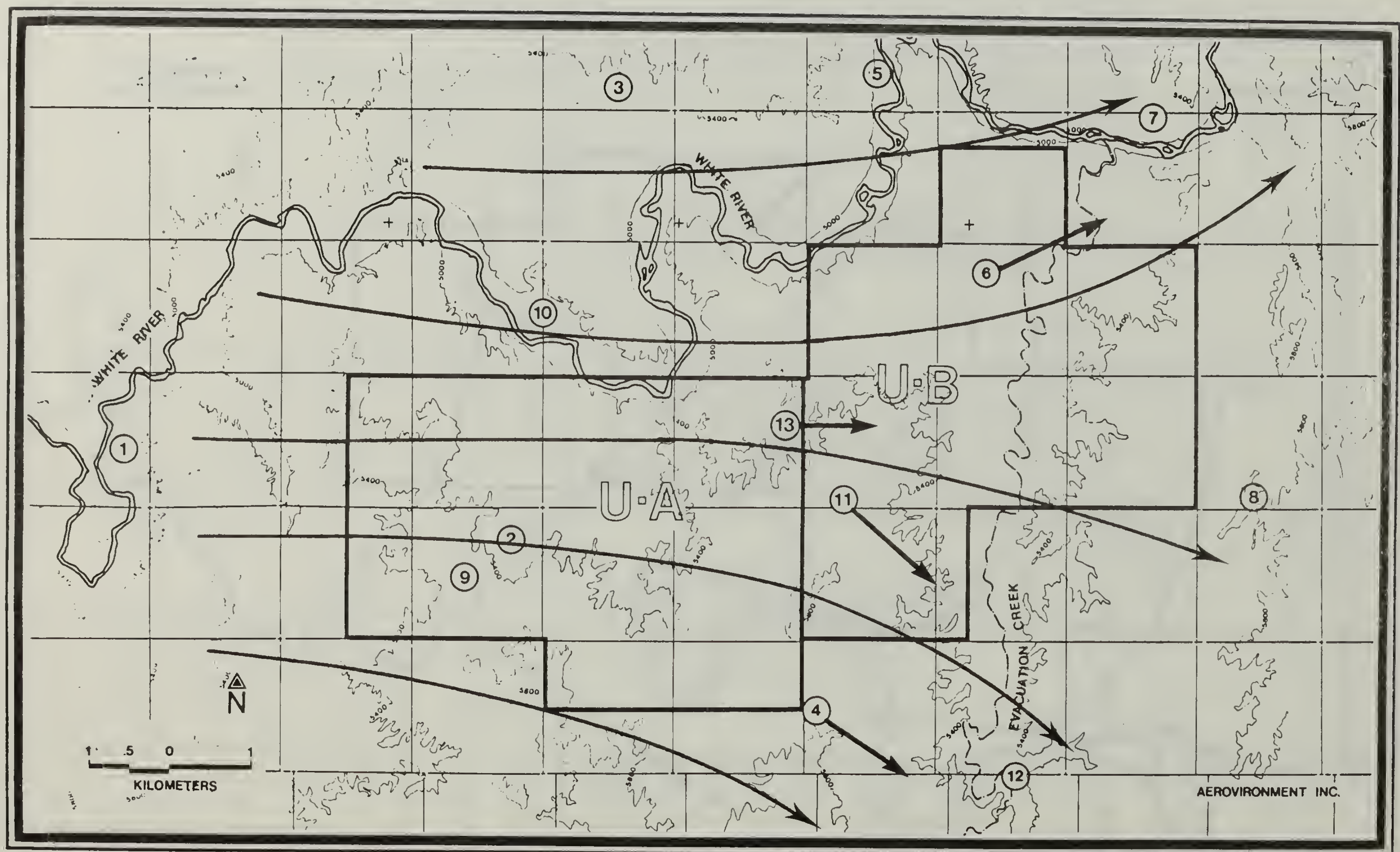


FIGURE 27 Typical airflow pattern on the tracts Ua and Ub in the morning in October 1977.



Wind Vector

2m/s

Streamline

FIGURE 28 Typical airflow pattern on the tracts Ua and Ub in the afternoon in January 1977.

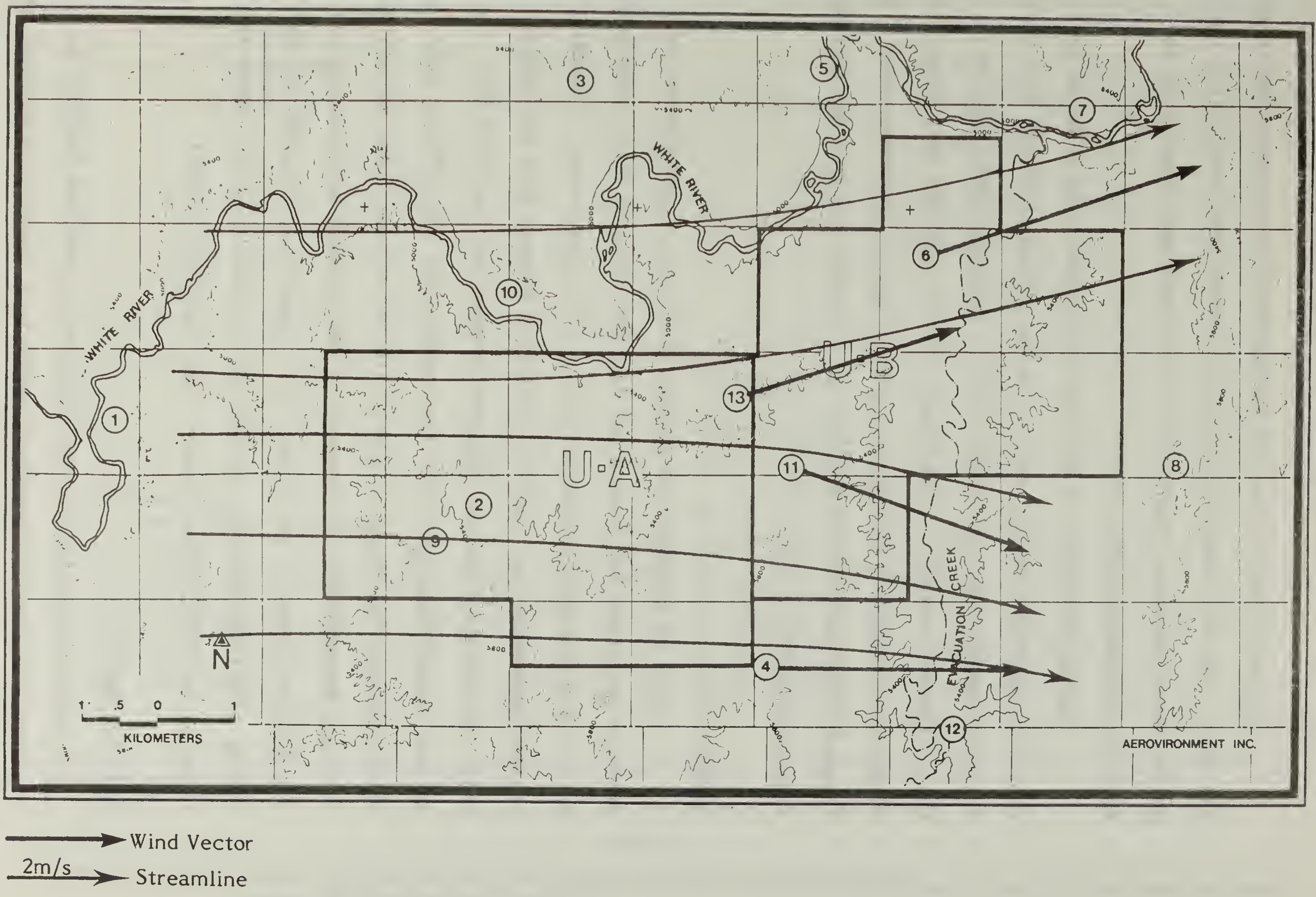


FIGURE 29 Typical airflow pattern on the tracts Ua and Ub in the afternoon in July 1977.

Figures 30 and 31 give the average hourly wind speed for January and July. The July Interim and Baseline speeds were practically the same during the afternoon. January 1977 wind speeds were lower than the Baseline averages but the pattern is similar.

Figures 32 through 35 show the directional wind roses at the monitoring stations on the tract using the mid-month of the four seasons (January, April, July and October 1977). Although individual months may have different prevailing directions, ESE has been the most prevailing direction at site A-6 throughout the Baseline and Interim periods. The frequent occurrence of the ESE wind is a direct result of the drainage flow that exists at A-6.

Temperature

Figure 36 presents the diurnal variation in temperature and standard deviation for January and July 1977 at site A-6. Superimposed on this are the average baseline values for a comparison. The daily maximum temperature was generally observed between 1400 and 1600 MST, while the daily minimum was observed between 0400 and 0700 MST. The average temperatures were $-5^{o}C$ for January 1977 and $23^{o}C$ for July 1977. These are shown on Figure 37 along with the maximum, mean and minimum for each month in 1977 as compared to the maximum, mean and minimum for the Baseline period. The highest July temperature observed was $36^{o}C$ during July 1976 (Baseline period) and the lowest January temperature observed was $-26^{o}C$ during January 1976 (Baseline period).

Relative Humidity

On the tract the diurnal variation of relative humidity is approximantely the reciprocal of temperature, indicating that the amount

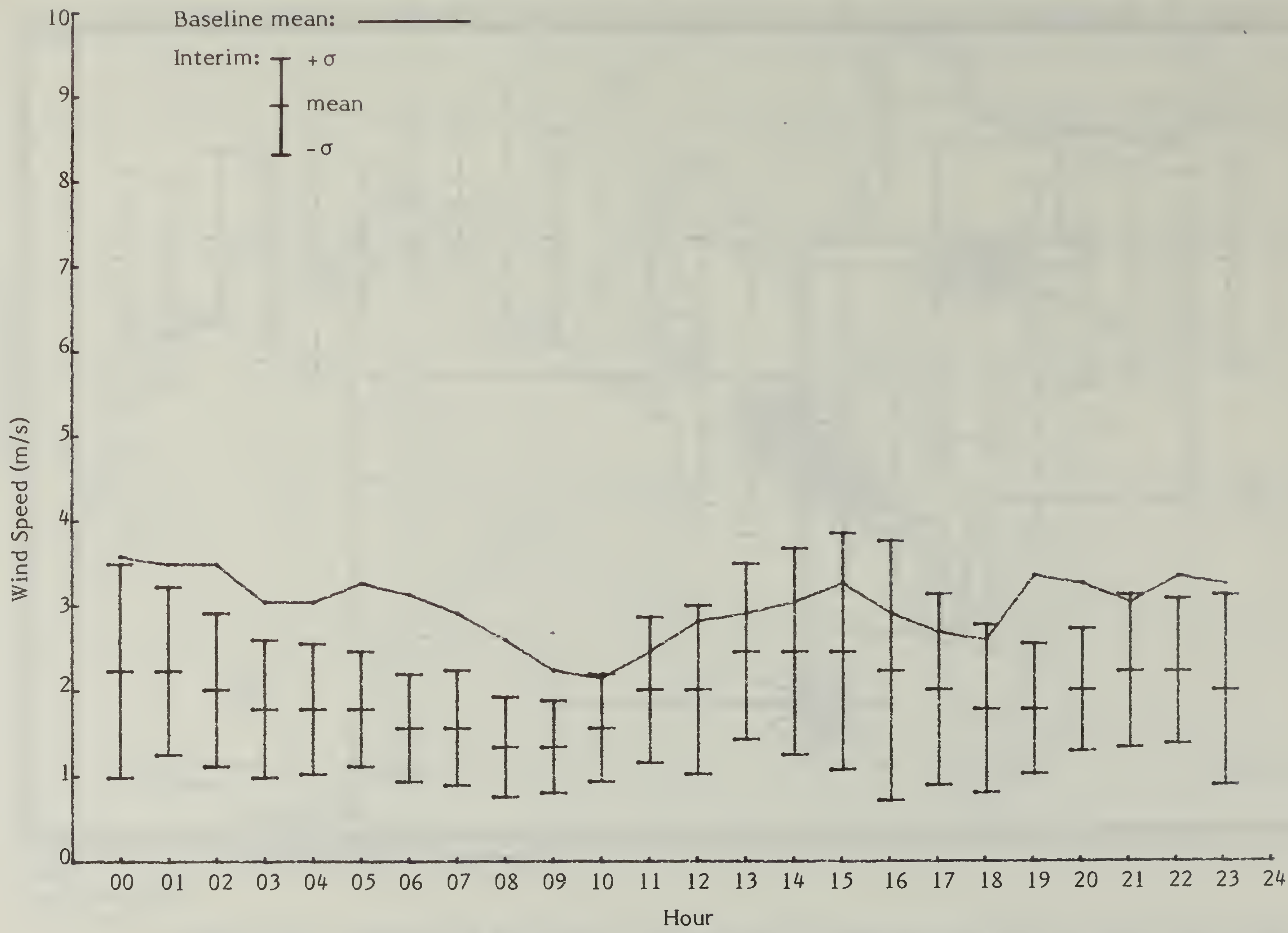


FIGURE 30. Diurnal variation of mean wind speeds and their standard deviations, compared to the baseline means at site A6 during winter (January).

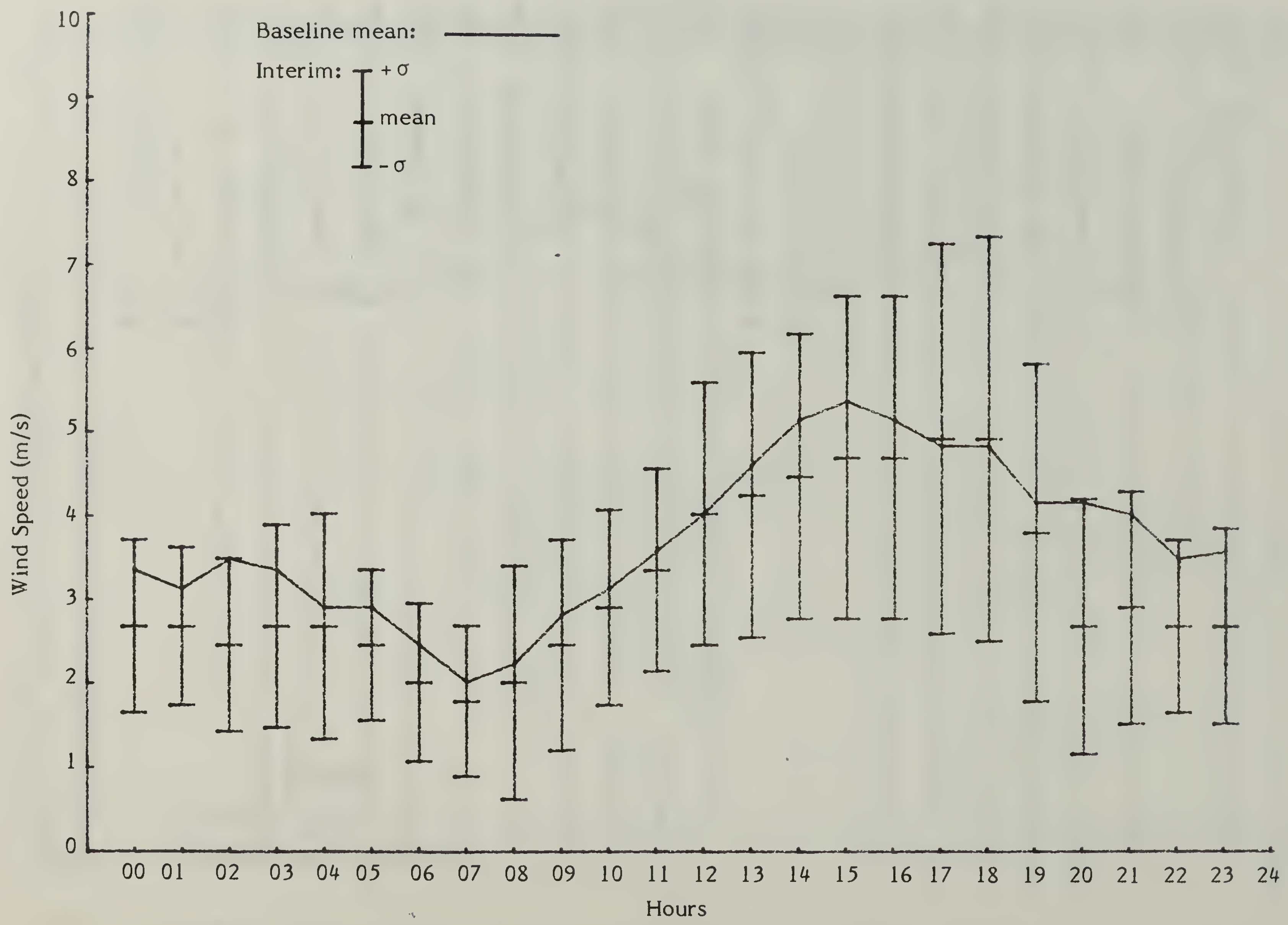


FIGURE 31. Diurnal variation of mean wind speeds and their standard deviations, compared to the baseline means at site A6 during summer (July).

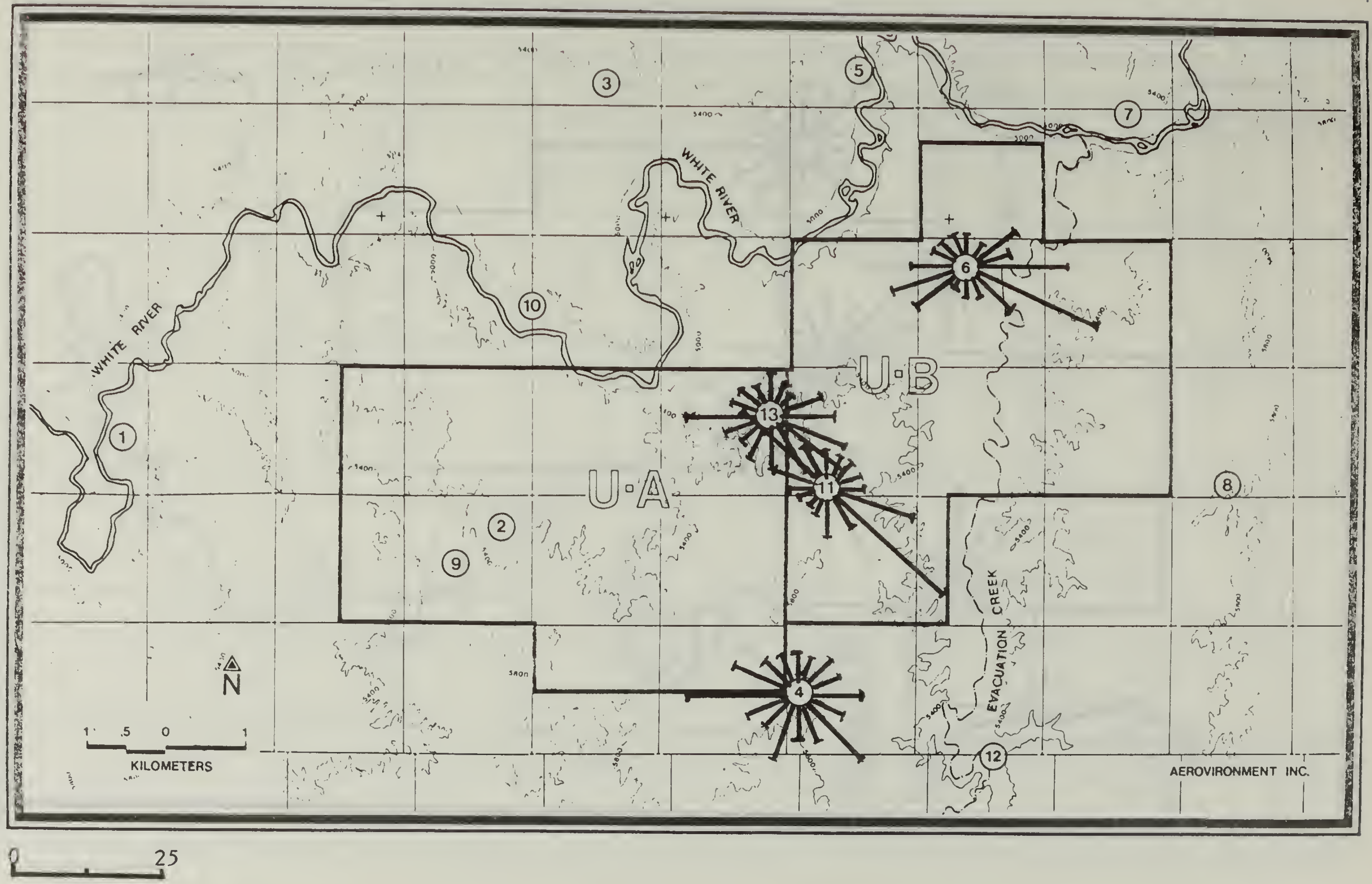


FIGURE 32. Directional wind roses at the monitoring stations on the tracts for January 1977. The length of each bar represents the frequency of winds from the direction towards which the bar points.

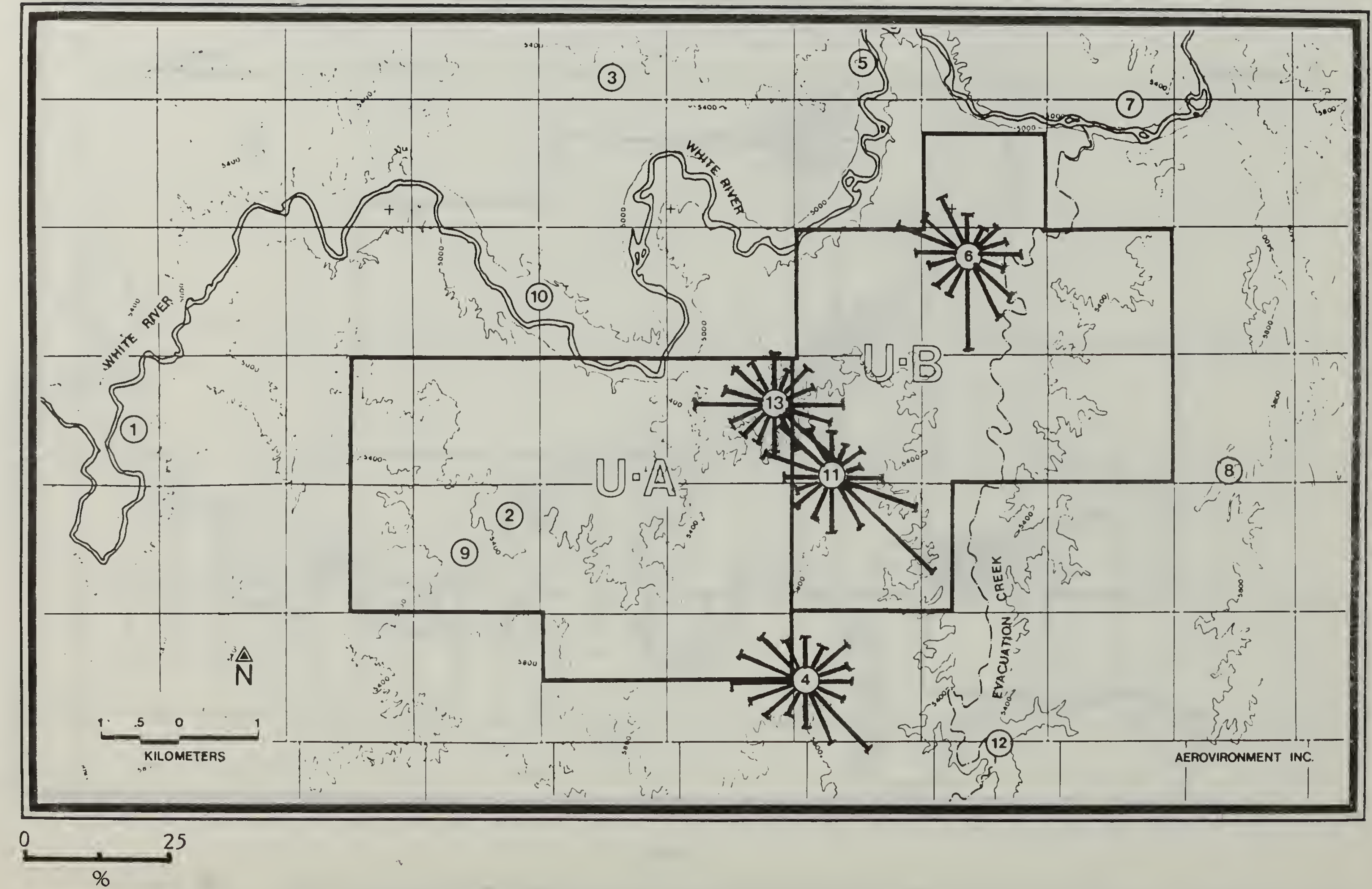


FIGURE 33. Directional wind roses at the monitoring stations on the tracts for April 1977. The length of each bar represents the frequency of winds from the direction towards which the bar points.

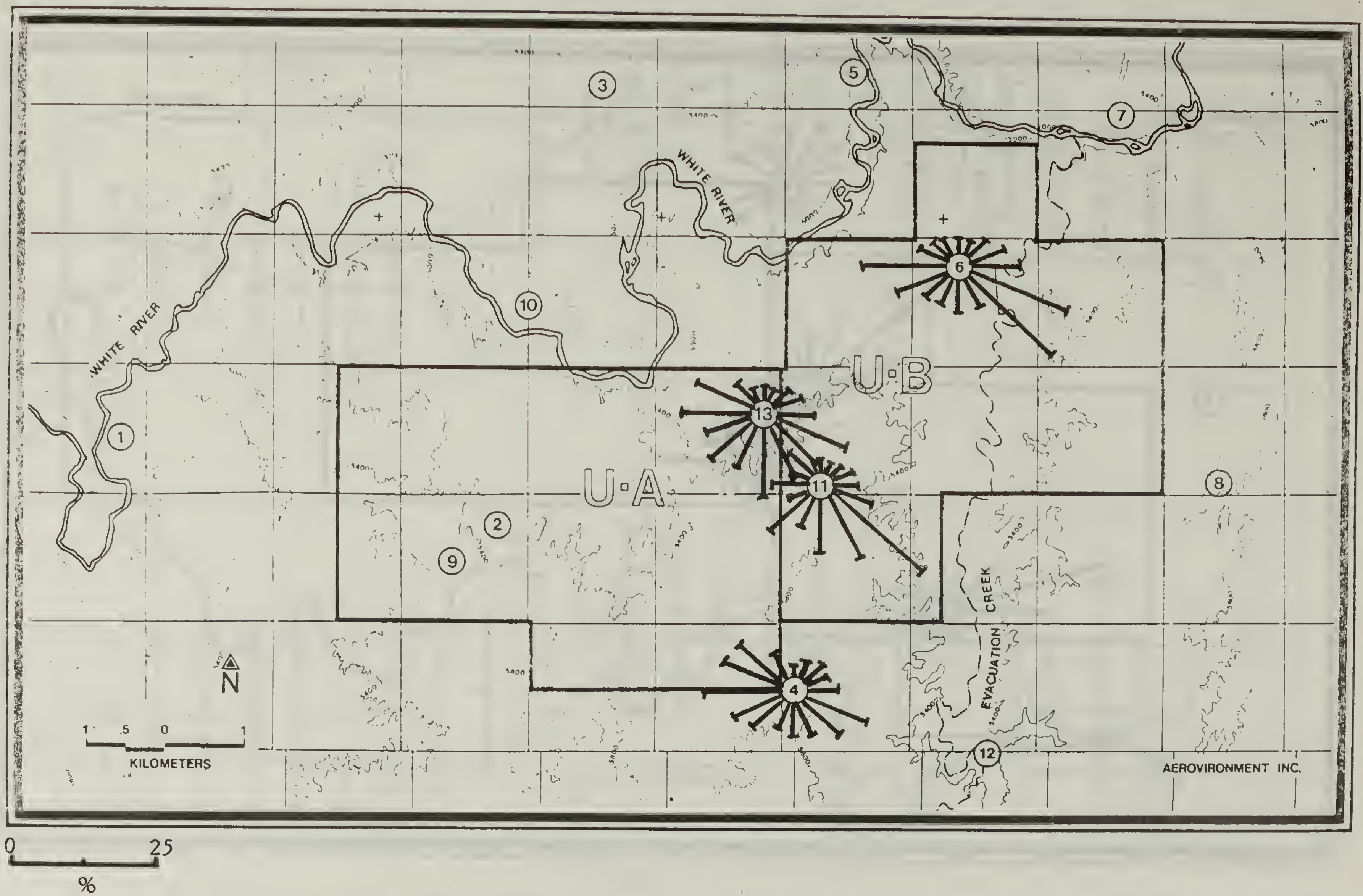


FIGURE 34. Directional wind roses at the monitoring stations on the tracts for July 1977. The length of each bar represents the frequency of winds from the direction towards which the bar points.

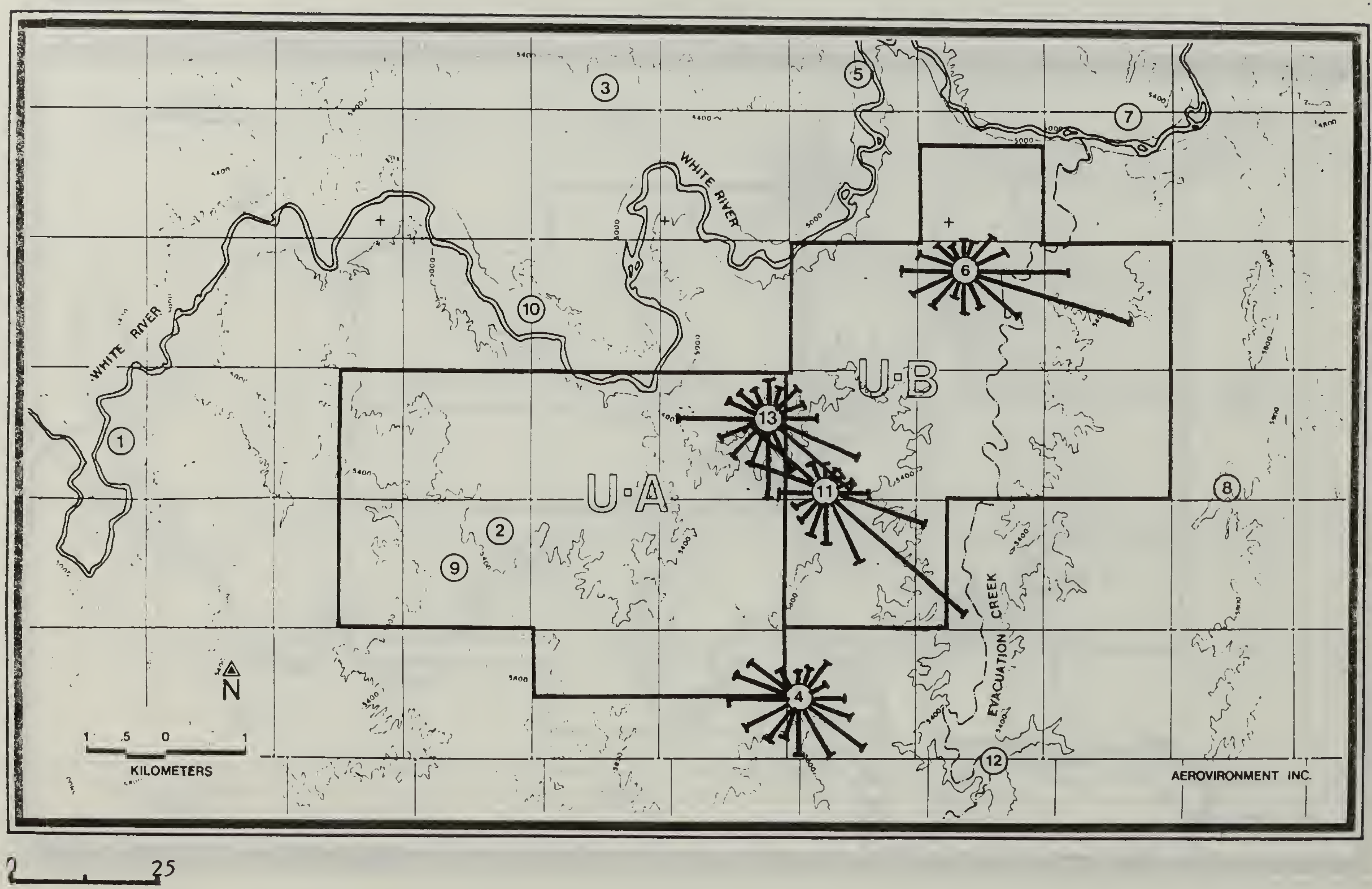


FIGURE 35. Directional wind roses at the monitoring stations on the tracts for October 1977. The length of each bar represents the frequency of winds from the direction towards which the bar points.

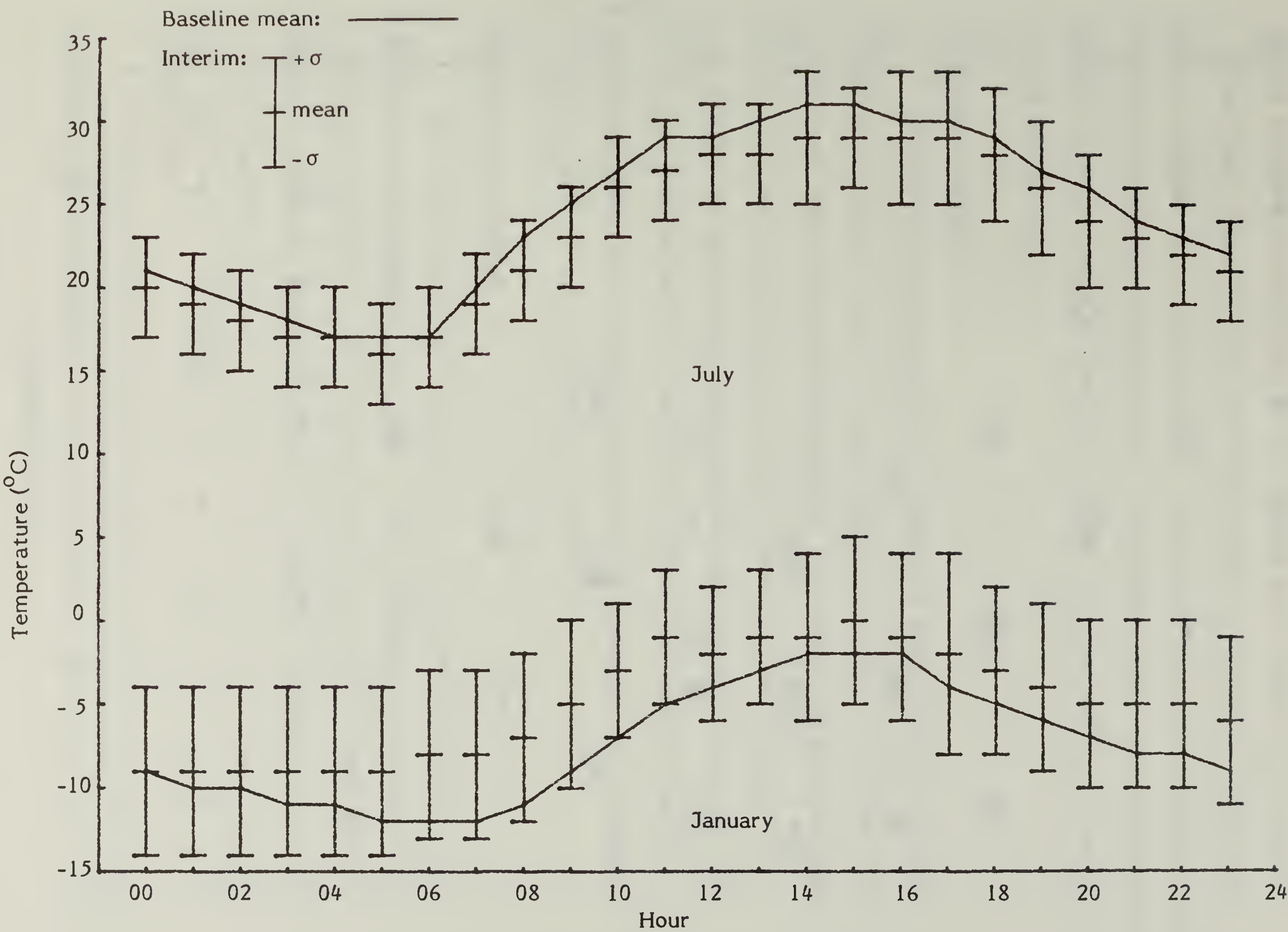


FIGURE 36. Diurnal variation of mean temperatures and their standard deviations compared to baseline means at site A6 during summer (July) and winter (January).

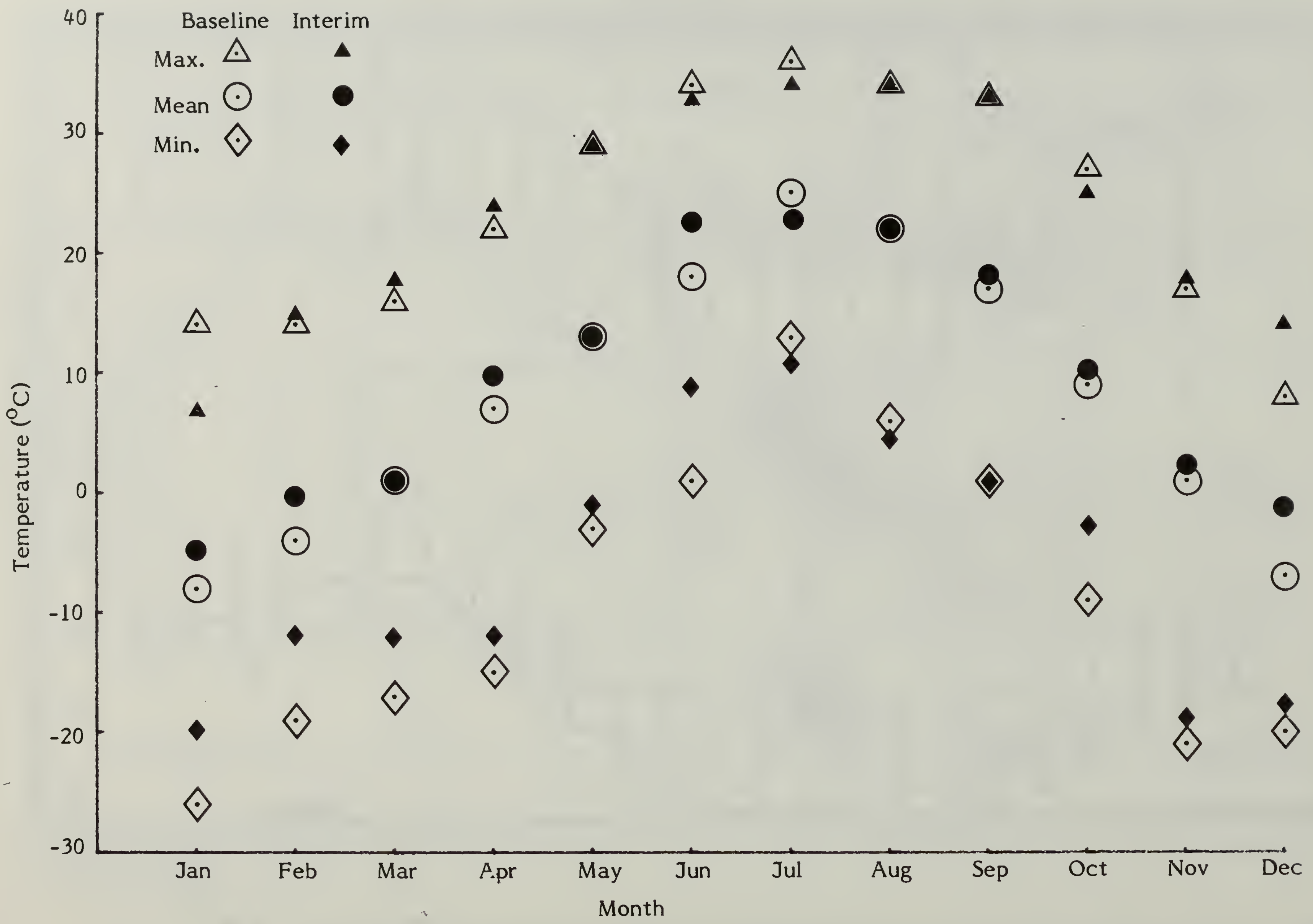


FIGURE 37. Monthly, mean, minimum and maximum temperatures at site A6 for the Interim Period (1977) and Baseline Period (1975, 1976).

of moisture in the air remains fairly constant during the day. Figures 38 and 39 show the diurnal trend of the average and standard deviations for a winter month (January 1977) and summer month (July 1977). The air was drier in summer than in the winter. The highest average readings were found in winter from 0400 through 0800 MST. The lowest values were found during summer afternoons between 1400 and 1600 MST. No change from the baseline period was observed.

Barometric Pressure

Figure 40 gives the maximum, minimum and mean barometric pressure at site A-6 for both the Baseline and Interim periods. The highest value observed was 646 mm of Hg during November 1977 (Baseline) and the lowest value of 610 mm of Hg during March 1977 (Interim). During the period from October to March the winter storms caused the lowest readings and the basin highs during this time period brought the highest readings. During the summer the air mass systems were much weaker and consequently not much change in the pressure was evident.

Net Solar Radiation

Net solar radiation is a factor to be considered in photochemical processes and atmospheric stability. Figure 41 shows the average hourly total solar radiation on tract during the winter (January 1977) and Figure 42 shows the summer (July 1977). Both periods showed no change from the Baseline period.

Diffusivity

The dispersion or dilution of windborne effluents in the atmospheric boundary layer depends greatly on the turbulence intensity or the diffusivity

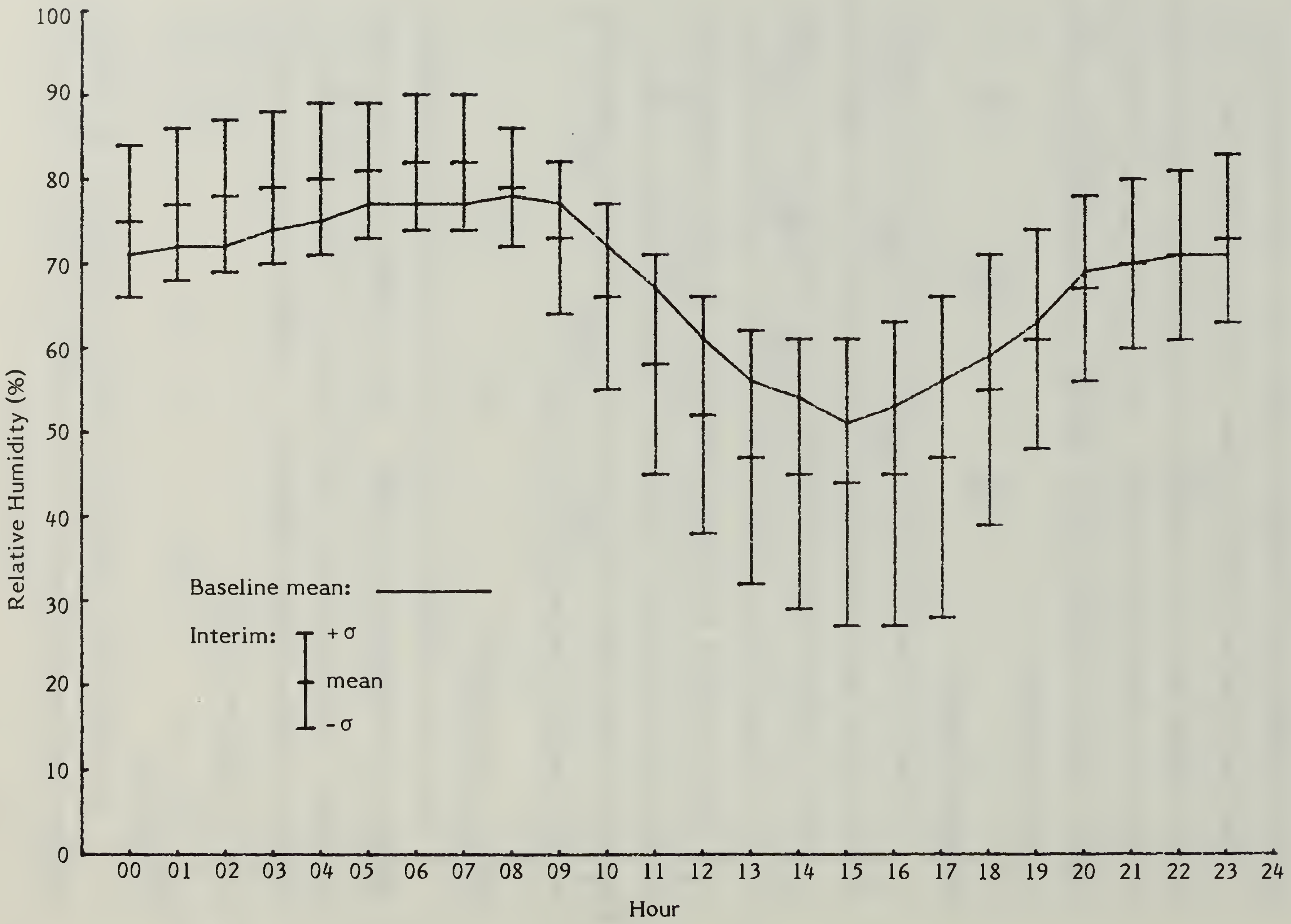


FIGURE 38. Diurnal variation of mean relative humidity readings and their standard deviations compared to the baseline means at site A6 during winter (January).

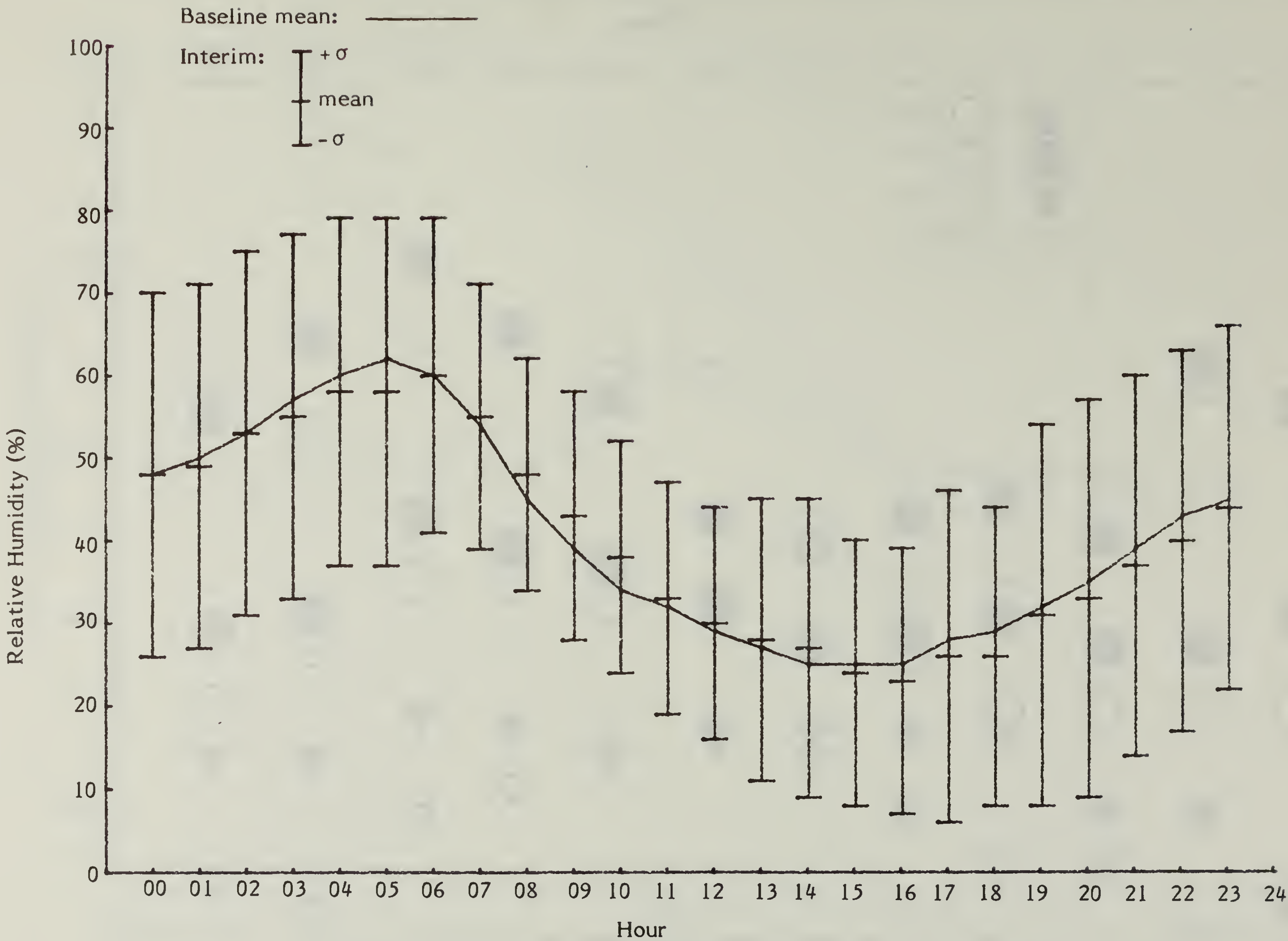


FIGURE 39. Diurnal variation of mean relative humidity readings and their standard deviations, compared to the baseline means at site A6 during summer (July)

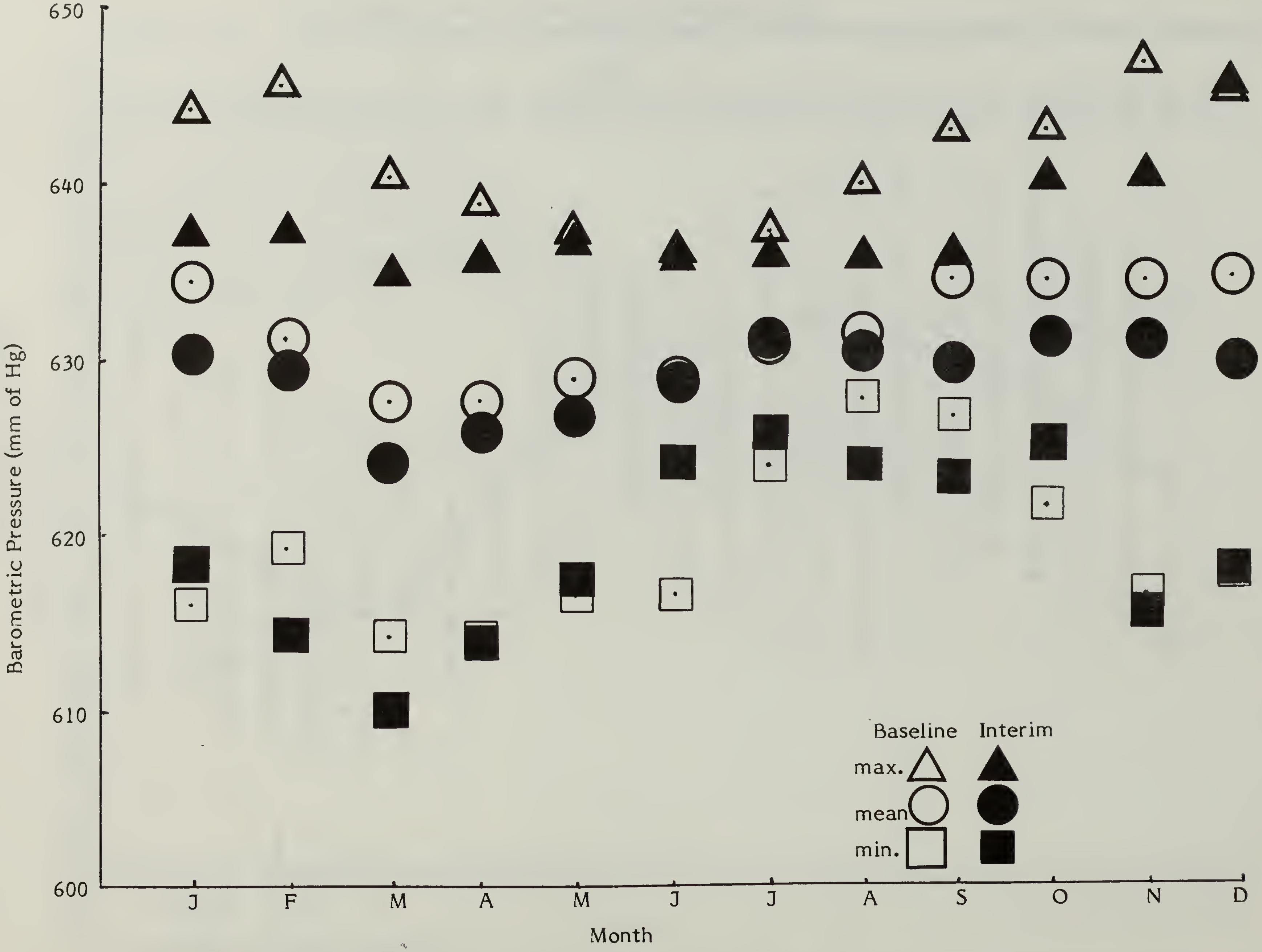


FIGURE 40. Monthly mean, maximum, minimum barometric pressure at site A6 for the Interim (solid) and the Baseline (open) Periods.

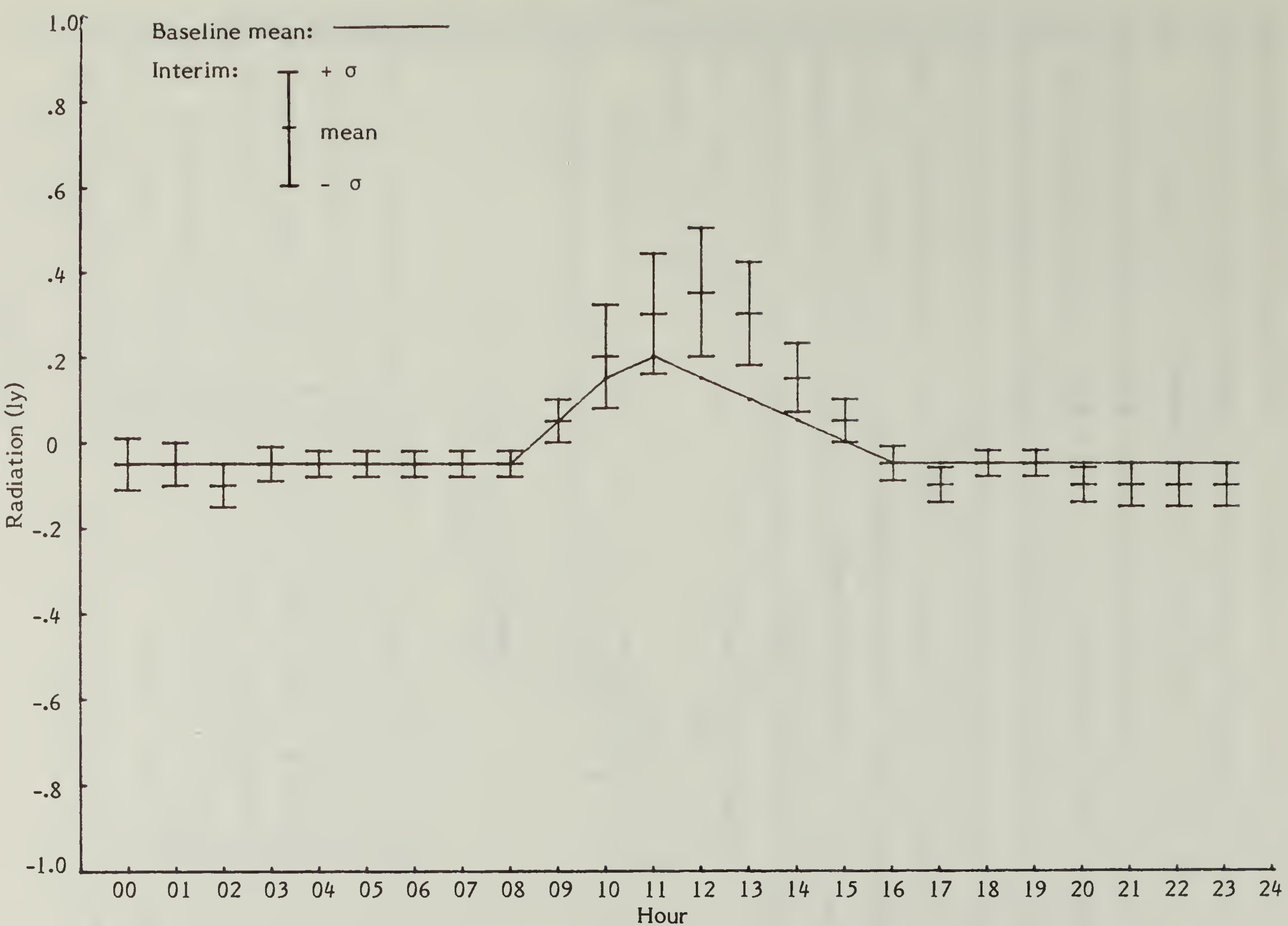


FIGURE 41. Diurnal variation of the mean and standard deviations of net solar radiation over the tracts for January 1977, compared to the baseline mean.

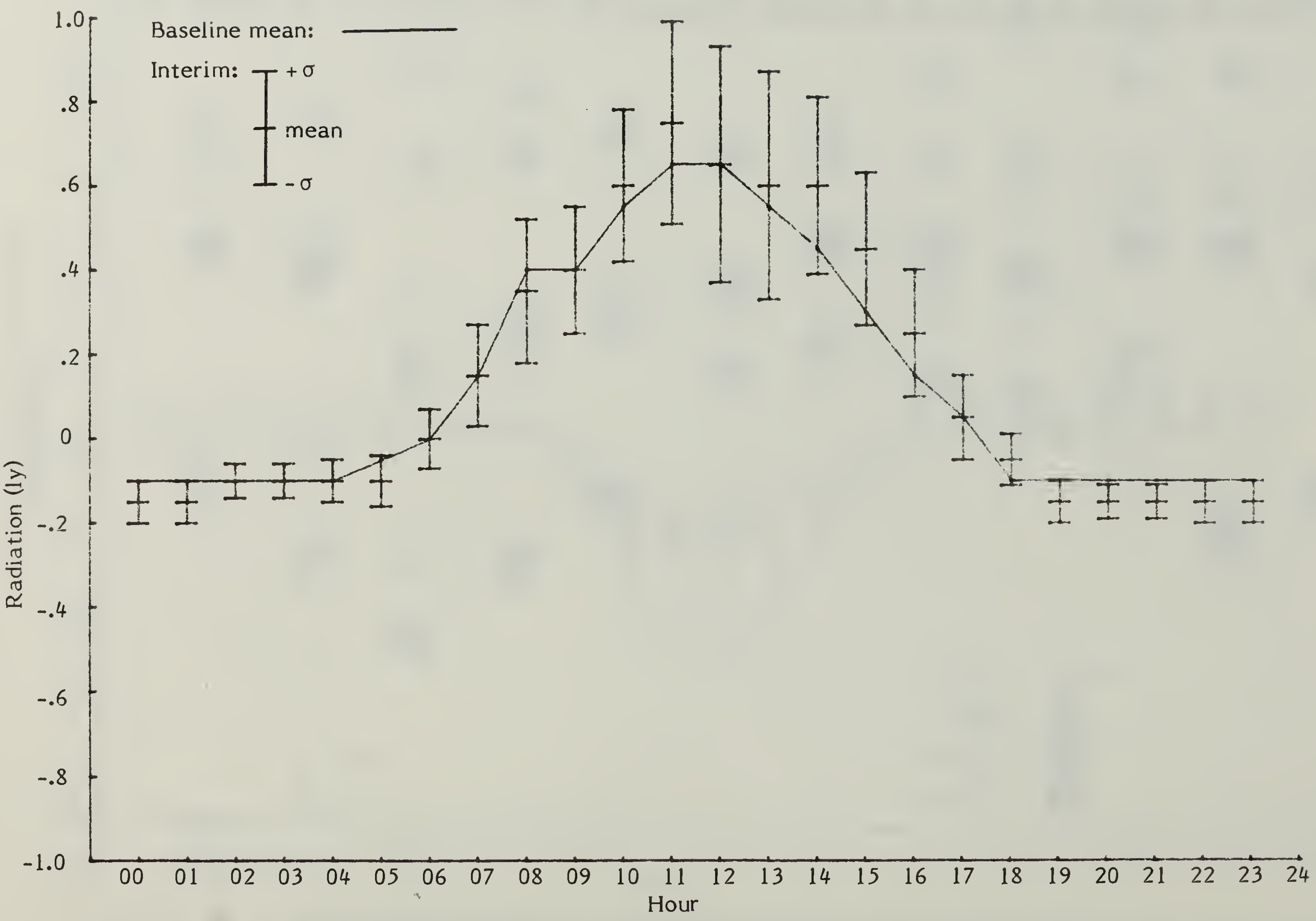


FIGURE 42. Diurnal variation of the mean and standard deviations of net solar radiation over the tracts for July 1977, compared to the baseline mean.

of the atmosphere. There are a number of ways of defining this diffusivity, based both on direct measurements of turbulence as well as on indirect inference of turbulence from other factors related to atmospheric mixing.

One indirect way of estimating this diffusivity is by means of temperature soundings, which can be used to describe the vertical stability of the atmosphere. Knowing the stability, one can then estimate the numerical values of dispersion parameters from experimentally derived stability/diffusion correlation curves, e.g., Pasquill-Gifford curves (Gifford, 1961). However, this approach has in itself certain disadvantages and limitations. The Pasquill-Gifford curves were based mostly on ground level concentration measurements made only out to 800 m downwind of a ground level source over smooth, flat terrain. The "Turner Workbook" (Turner, 1970) curves have a similar origin. A more reasonable and direct method is described by MacCready, et al(1974).

The dispersion of a plume is often described mathematically by the Gaussian diffusion equation having the following form:

$$\frac{X}{Q} = \frac{1}{\sigma_y \sigma_z U} \exp \left[-\frac{1}{2} \left[\frac{H}{\sigma_z} \right]^2 \right] \qquad (1)$$

where X is the surface concentration, Q is the source emission rate, σ_y, σ_z are horizontal and vertical dispersion coefficients, respectively, U is the mean wind speed, and H is the effective stack height. MacCready, et al (1974) show that, at downwind distances in excess of the order of a kilometer, $\sigma_y^2 \sim \sigma_v t$ and $\sigma_z^2 \sim \sigma_w t$ where σ_v and σ_w are the root-mean-square turbulence fluctuations in the lateral wind speed u and the vertical wind speed w and t is the time of plume travel. Using these relations for H = 0, and

noting that the location of a receptor is given by x = Ut, one can write

$$\frac{X}{Q} \sim \frac{1}{(\sigma_v \sigma_w)^{1/2} x} \tag{2}$$

This relationship, with H taken as zero, is valid along the centerline of a plum released aloft, or at the surface for emissions released at the surface (although ground effect makes the constant of proportionality twice as great in the latter case as in the former). For other cases the decay in X/Q with x is even greater because of the growth of σ_z in the exponential term of the full equation.

For receptors off the plume centerline, an exponential term is included, which includes concentration decay with lateral distance, y, from the centerline:

$$\exp\left(-\frac{ky^2U}{\sigma_v x}\right) \tag{3}$$

Its impact will always be such as to decrease the concentration expected.

a. Lateral and vertical wind speed fluxuations $(\sigma_v \sigma_w)^{1/2}$

Using this approach, one can have a quantitative characterization of the turbulent intensity, using the measurement of $\sigma_v (o_v \sim U\sigma_\theta)$ and of σ_w made continuously at station A-6. Table 32 presents the frequency distribution of the quantity $(\sigma_v \sigma_w)^{1/2}$ for both the Baseline and Interim periods. Table 32 shows that the same general trend persisted in both periods. The normal ranges of $\sqrt{\sigma_v \sigma_w}$ were between 0.2 and 0.4. One observes that the values approximately hold also for the Baseline period.

On a diurnal basis low values were generally observed at night and high values in the afternoon. One may notice similar diurnal or seasonal

TABLE 32. Relative frequency distribution (%) of $\sqrt{\sigma_v \sigma_w}$ at site A6 for the Baseline and Interim Periods.

Seasons	$\sqrt{\sigma_v \sigma_w}$ **									Total No. of observations
	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	>1.4	
BASELINE										
Spring	3	31	24	15	14	8	4	1	0	3,159
Summer	0	25	30	19	14	9	3	0	0	3,847
Fall	1	40	27	18	8	4	1	1	0	2,479
Winter	5	69	22	3	1	0	0	0	0	2,094
INTERIM										
Spring	2	42	23	15	10	6	2	0	0	2,208
Summer	0	33	25	16	16	8	2	0	0	2,100
Fall	1	49	24	14	8	3	1	0	0	2,183
Winter	3	59	26	8	3	1	0	0	0	2,159

* Based on the year 1976 alone
** Each interval of $\sqrt{\sigma_v \sigma_w}$ spans 0.2 m/s and commences with the value shown.

patterns in solar radiation and wind speed. Such correlation illustrates the principle that high downward flux of solar radiation usually induces instability. High winds cause increases in σ_W due to mechanical turbulence in complex terrain, such as the Ua and Ub tracts.

In evaluating the dispersion potential on the tract, the parameter $\sqrt{\sigma_V \sigma_W}$ should not be considered alone. Equation (2) is only true for ground release or for receptors at plume centerline level for elevated sources. The effect of elevated sources on maximum ground level concentration at receptors at ground level has a strong dependence on the "effective stack height." Effective stack height is a combination of the physical stack height and plume rise. When plume rise is under proper perspective, an evaluation of the over-all dispersion potential for elevated sources is meaningful.

b. Wind direction fluctuation, σ_θ

Consistent with the position that σ_V and σ_W depict turbulent intensity better than vertical atmospheric stability does as defined by temperature soundings or other methods, one can also follow the general convention and categorize turbulent intensity into different "stability" (or better, "diffusion") classes. Using σ_θ data at site A-6, the frequency distribution of different "stability" classes is computed and presented in Table 33. The classification scheme used follows that in Atomic Energy Safety Guide 23 (AEC/1972) and appears in Table 34. This exercise is done to emulate the classical Pasquill-Gifford stability schemes for those who are accustomed to and are more comfortable with this type of classification. It is done also for those who will use σ_θ in their model instead of $\sqrt{\sigma_V \sigma_W}$. Again, it should be stressed that the Pasquill-Gifford stability curves are intended only for flat or smoothly rolling terrain.

TABLE 33. Relative frequency distribution (%) of stability classes at site A6 for the Baseline and Interim Periods. Table III-6 defines the classes A through G.

		Stability Classes						
Period	Season	A	B	C	D	E	F	Total # of obs.
Baseline	Winter	.7	.8	6.2	27.2	46.8	18.3	2,204
	Spring	.3	.5	5.4	29.3	58.4	6.1	2,208
	Summer	0	0	3.1	36.5	54.6	5.8	2,117
	Fall	0	.4	6.2	27.2	46.4	19.8	2,182
Interim	Winter	.2	1.8	7.5	26.4	49.6	14.5	2,160
	Spring	.3	2.3	14.0	29.5	44.7	9.2	2,208
	Summer	.1	1.2	15.8	32.6	44.8	5.5	2,101
	Fall	0	.7	12.1	25.1	47.6	14.5	2,184

TABLE 34. Classification of atmospheric stability.

Stability Classification	Pasquill Categories	σ_θ*
Extremely unstable	A	25.0°
Moderately unstable	B	20.0°
Slightly unstable	C	15.0°
Neutral	D	10.0°
Slightly stable	E	5.0°
Moderately stable	F	2.5°

Source: Atomic Energy Safety Guide 23 (AEC, 1972)

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* Standard deviation of horizontal wind direction fluctuation over a period of 15 minutes to 1 hour. The values shown are averages for each stability classification.

When the whole year is considered, stability classes D and E are most prevalent on the tract. Data collected at site A-6 shows that variability in stability classes with atmospheric conditions is greatest in winter and the over-all pattern is still tending toward a stable atmosphere. One should also note the similarity in trends in σ_θ and $\sqrt{\sigma_v \sigma_w}$; they both measured approximately the same thing. Comparison with the baseline value shows no significant changes.

c. Temperature difference, ΔT

As mentioned earlier, a complete dispersion picture must also include the effect of plume rise. The total effect of all influencing parameters on dispersion will be discussed below. Two meteorological parameters greatly influence the height of a plume; namely, the atmospheric stability and wind speed. Vertical atmospheric stability can be best defined by ΔT data. In equations derived by Briggs (1974), for calculating plume height only three atmospheric stability classes are needed. The classification scheme is listed in Table 35.

Figures 43 and 44 present the diurnal variation of ΔT collected at site A-6 for two typical months, January and July. Note that very stable or slightly stable atmospheric conditions prevailed in early morning and evening. In the afternoon neutral or unstable conditions were a general rule. Comparison of the two months indicates that January has about 4 more hours of very stable conditions coinciding with the longer winter nighttime.

The frequency distribution of stabilities based on ΔT appears in Table 36, which shows that very stable conditions occurred more frequently in the winter and fall, whereas unstable or neutral activities occurred more often in the spring and summer. One thing that should be mentioned is

TABLE 35. ΔT stability scheme.

Stability	ΔT ($^{o}C/100m$)
1. Unstable and Neutral	<-0.5
2. Slightly Stable	-0.5 to 1.5
3. Very Stable	>1.5

TABLE 36. Relative frequency distribution (%) of ΔT at site A6 for the Interim Period.

Season	Stability: Unstable or Neutral	Stability: Slightly Stable	Stability: Very Stable	Total No. of Observations
Winter	38	21	41	2,160
Spring	43	25	32	1,797
Summer	42	25	33	2,172
Fall	40	19	41	2,184
All Year (1977)	41	23	36	8,313

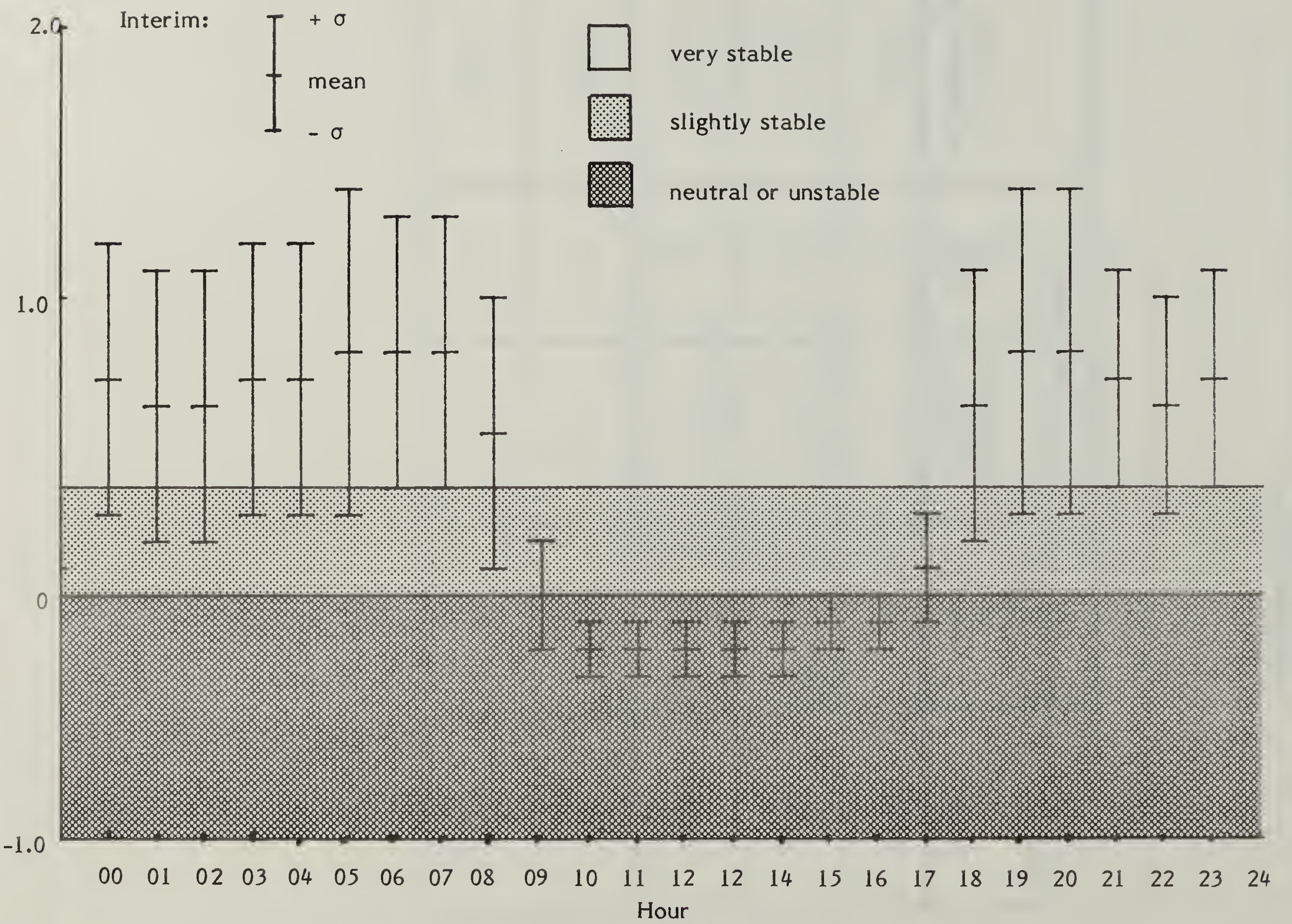


FIGURE 43. Diurnal variations of ΔT with means and standard deviations by hour for site A6 in January 1977.

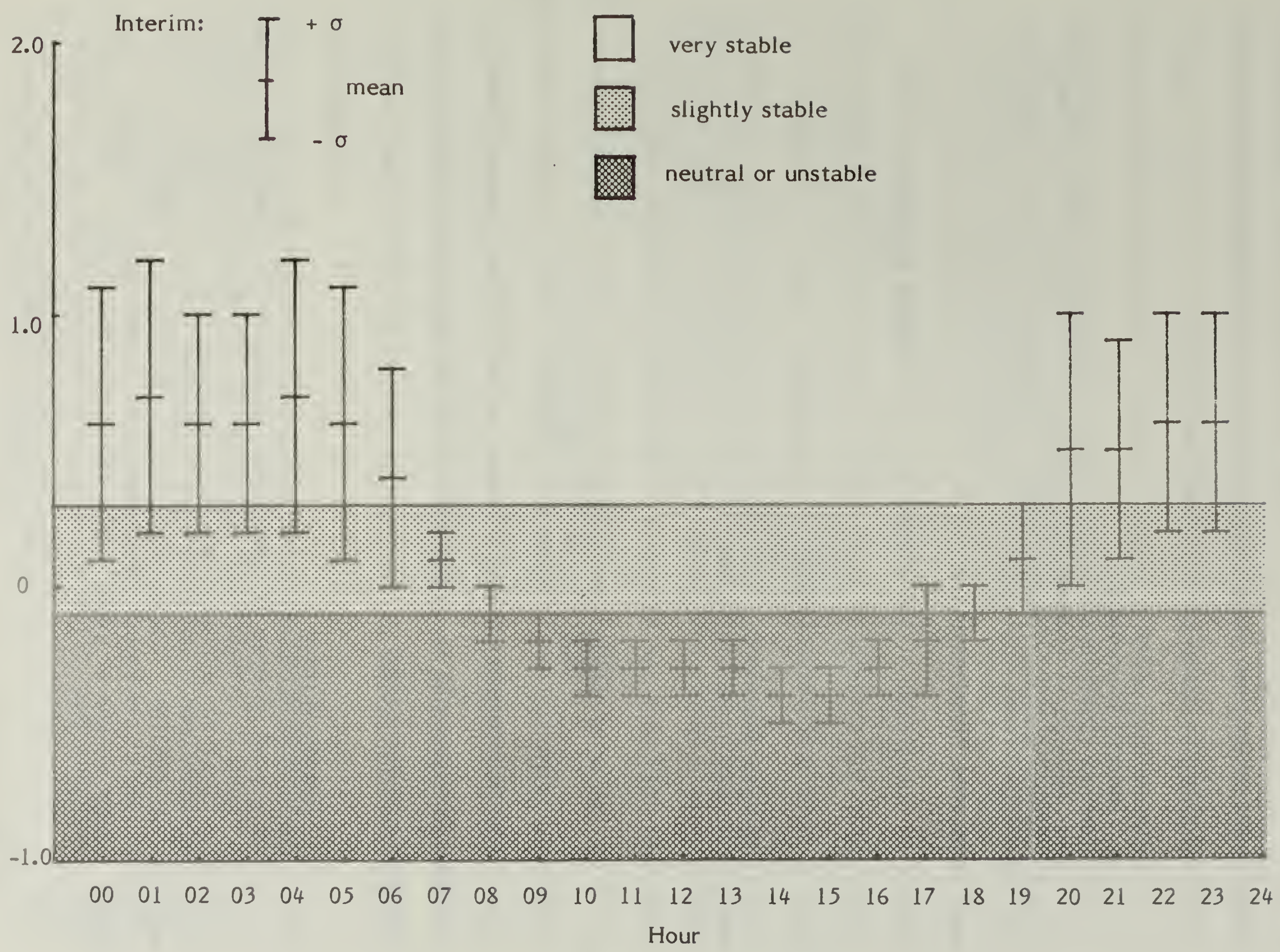


FIGURE 44. Diurnal variations of ΔT with means and standard deviations by hour for site A6 in July 1977.

the total accuracy of the ΔT system at site A-6. The system for the Interim year measures ΔT to within $\pm 0.1^{o}C/20$ meters over the measurement interval. Accuracy was below this level in the Baseline period; hence no comparison of the ΔT data is attempted for these two periods.

d. General Discussion

This section is intended to combine the effects of all parameters that have significant influence on the dispersion field. It should be understood that turbulence intensity, as measured by $\sigma_v \sigma_w$ or σ_θ is a measure of the mixing of the atmosphere, while ΔT is a measure of the stability of the atmosphere as it affects plume rise. With a ground level release, high turbulence intensity (i.e., $\sqrt{\sigma_v \sigma_w}$ or σ_θ) is associated with good dispersion potential. The dispersion picture can become altered, however, when a source with plume rise is considered. Two meteorological parameters influence the height of a plume, namely vertical atmospheric stability and wind speed. The combined effect of these two parameters with turbulence intensity really makes the dispersion picture a three dimensional matrix. In the discussion that follows, a distinction between ground and elevated releases will be made, since each has definitely different dispersion characteristics.

1. <u>Ground Release</u>

For ground release of non-buoyant plumes or for receptors at plume centerline level for elevated sources, dispersion takes a simpler form and equation (2) applies. Concentration X/Q is inversely proportional to $\sqrt{\sigma_v \sigma_w}$. Lower values of $\sqrt{\sigma_v \sigma_w}$ imply higher concentrations. Thus dispersion potential will necessarily follow the trend of $\sqrt{\sigma_v \sigma_w}$. Therefore, judging from $\sqrt{\sigma_v \sigma_w}$ alone, one could very well obtain a relative picture for

dispersion on the tract. The $\sqrt{\sigma_v \sigma_w}$ frequency distribution table (Table 32) indicates that good dispersion potential can be expected in summer with a value of $\sqrt{\sigma_v \sigma_w}$ greater than 0.8 happening 26% of the time in that season. Adverse conditions will persist in winter with a value of $\sqrt{\sigma_v \sigma_w}$ below 0.4 happening 62% of the time within that season. Since good correlation can be obtained among wind speed, solar radiation and $\sqrt{\sigma_v \sigma_w}$, as indicated previously, one may conclude such conditions will most probably occur on a winter night with low wind speed.

2. Elevated Release

Another term

$$\exp\left\{ - \frac{1}{2} \left(\frac{kH^2U}{\sigma_w X} \right) \right\} \tag{4}$$

has to be included in equation (2) to account for the effect of elevated release on the ground. Thus we have:

$$\frac{X}{Q} = \frac{1}{\sqrt{\sigma_v \sigma_w} X} \exp\left\{ - \frac{1}{2} \left(\frac{kH^2U}{\sigma_w X} \right) \right\} \tag{5}$$

It should be noted that this additional term for elevated sources acts always to decrease concentrations. Therefore, an elevated stack must produce lower ground concentrations than does a ground release from the same source.

The inclusion of an extra term makes the definition of an adverse condition more difficult. Not only does the value of X depend on the value of $\sqrt{\sigma_v \sigma_w}$, it also depends on the stability of the atmosphere and the strength of wind speed. This dependence, however, is not straight forward. The interaction of wind speed, stability and turbulence in the dispersion of pollutants is discussed below.

- Turbulence Intensity

Although increasing turbulence results in increased dilution, the combined effect of high turbulent intensity and high wind speed can produce relatively high ground level concentrations close to the source. In such combinations the role of stability is weak. This condition should be regarded as one conducive to high ground level concentration. However, as will be shown later, this condition was not observed at station A-6.

In physical terms, this phenomenon is explained by the effect of these conditions on plume rise. High wind speed tends to dominate stability in plume rise and to produce very low plume rise. When this situation occurs with the presence of high turbulence intensity, the plume will mix to the ground soon after being released, thereby resulting in higher ground concentrations close to the stack then would occur with lower wind speed or or turbulence.

- Vertical Atmospheric Stability

Stability predominantly offsets plume rise in a low wind speed case. Because of this, a very stable atmosphere is capable of producing higher ground level concentrations than those occurring with a combination of high wind speed and high turbulence intensity. In both cases reduced plume rise results in higher ground level concentrations when the plume mixes to the ground; when this mixing occurs under stable conditions, the dilution is less than when it occurs under stable conditions, the dilution is less than when it occurs under more turbulent conditions. Therefore, the combination of low wind speed and a very stable atmosphere should also be regarded as an adverse condition, especially in complex terrain air from flowing freely over higher downwind terrain, which further aggravates the impact.

- Wind Speed

Wind speed plays two conflicting roles in affecting ground concentrations of gaseous pollutants from elevated sources. One effort of wind speed is to transport more air past the source; thus, higher wind speed tends to decrease concentrations. Another effect of wind speed is to reduce plume rise; thus higher wind speed in this case will result in higher ground level concentrations. In low turbulence, the transport effect dominates ground level concentrations. With greater turbulence, the decrease in plume rise becomes the more important effect.

Summarizing the above discussion leads to the following:

a. High wind speed coupled with high turbulent intensity produces an adverse condition, and the distance to maximum X/Q is shortest in this case. However, these conditions did not occur at station A-6.

b. Low wind speed with very stable atmosphere is also adverse to dispersion. The distance to maximum X/Q becomes shorter the more stable the atmospheric conditions.

3. Joint Frequency Distributions

Therefore, for elevated sources on the Ua/Ub tract most adverse conditions can be characterized by the two combinations of meterological parameters discussed in the last paragraph.

To facilitate in pinpointing the approximate time of the year in which the adverse combinations discussed above occur, joint frequency distributions of wind speed, wind direction, diffusivity and stability, were constructed for site A-6 for the Interim year. The joint frequency

distributions were categorized into vertical atmospheric stability classes, as defined by ΔT, and turbulent intensity (or diffusion) classes as defined by σ_θ. The classification schemes are shown in Tables 35 and 34 respectively. One will find the set of joint frequency distributions in Appendix A. This type of information, with some modifications, is useful also as input into many climatological dispersion models, such as the CDM model of EPA, to compute annual average of a particular pollutant.

Examining the entire set of joint frequency distributions, one finds the combination of very stable atmosphere with low wind speed (<3.5 m/s) occurred 23.5% of the time in the entire year, with such occurrences most frequent (30.6%) in the winter. Table 37 shows the relative frequencies of such occurrences by seasons and in the entire year.

The other condition classified as adverse to diffusion identified above was high wind speed coupled with high turbulence intensity. The combination of high wind speed (8 m/s or greater) and high turbulence intensity (A or B σ_θ class) did not occur at all on the tract.

TABLE 37. Relative frequency (%) of low wind speed (<3.5 m/s) combined with very stable atmosphere within each season and for the entire interim year at Site A6.

Season	Frequency (%)
Winter	30.6
Spring	18.9
Summer	18.0
Fall	26.4
All Year (1977)	23.5

REFERENCES

Atomic Energy Commission (1972): Safety guides for water cooled nuclear power plants. USAEC, Division of Reactor Standards, Washington, D.C. 20545. Safety Guide Number 23: Onsite Meteorological Programs.

Briggs, G. A. (1974): Diffusion estimation for small emissions. USAEC Report. ATDL-106NOAA.

Gifford, F. A. (1961): Uses of routine meteorological observation of estimating atmospheric dispersion. Nuclear safety 2 (4), 47-51.

Halligan, J. P. (1975): Toxic terpenes from Artemisia California. Ecology 56, 999-1003.

Lamb, R. G. (1977): A case study of stratospheric ozone affecting ground level oxidant concentrations. J. of Appl. Meteor. 16, 780-794.

MacCready, P. B., Jr., L. B. Baboolal, and P.B.S. Lissaman (1974); Diffusion and turbulence aloft over complex terrain. Paper presented at the AMS Symposium on Atmospheric Diffusion and Air Pollution, 9-13 September, Santa Barbara, CA. (AV TP 311, AeroVironment Inc., Pasadena, CA).

Rasmussen, R. A. (1972): What do the hydrocarbons from trees contribute to air pollution? JAPCA 22 (7), July.

Stasnick, W. N., Jr., and P. E. Coffey (1974): Rural and urban ozone relationships in New York State. JAPCA 24 (6), 564-568.

Staley, D. O., (1960): Evaluation of potential vorticity changes near the tropopause and the related vertical motions, vertical advection of vorticity and transfer of radioactive debris from stratosphere to troposphere. J. of Appl. Meteor. 17, 591-620.

Vukovich, F. M., W. D. Bach, Jr., B. W. Crissen, and W. J. King (1977): On the relationship between high ozone in the rural surface layer and high pressure systems. Atmospheric Environment 11, 967-983.

4.3 BIOLOGICAL RESOURCES

Biological resources monitoring for the two-year Environmental Baseline Monitoring Program was completed during January of 1977.

Interim monitoring work involves vegetation and terrestrial vertebrates. Data from a USGS Water Resources Division aquatic biology monitoring program will be incorporated into the data base as available. Data from ongoing Utah Division of Wildlife Resources and Bureau of Land Management programs will also be reviewed and incorporated as applicable.

The monitoring work uses techniques similar to those used in the Baseline program.

Figure 45 shows the monitoring sites for vegetation and animal monitoring activities.

4.3.1 Vegetation

The following material discusses the monitoring done as part of the Interim Monitoring Program conducted during 1977. Dr. Cyrus McKell is under contract to WRSP for the conducting of the vegetation monitoring program.

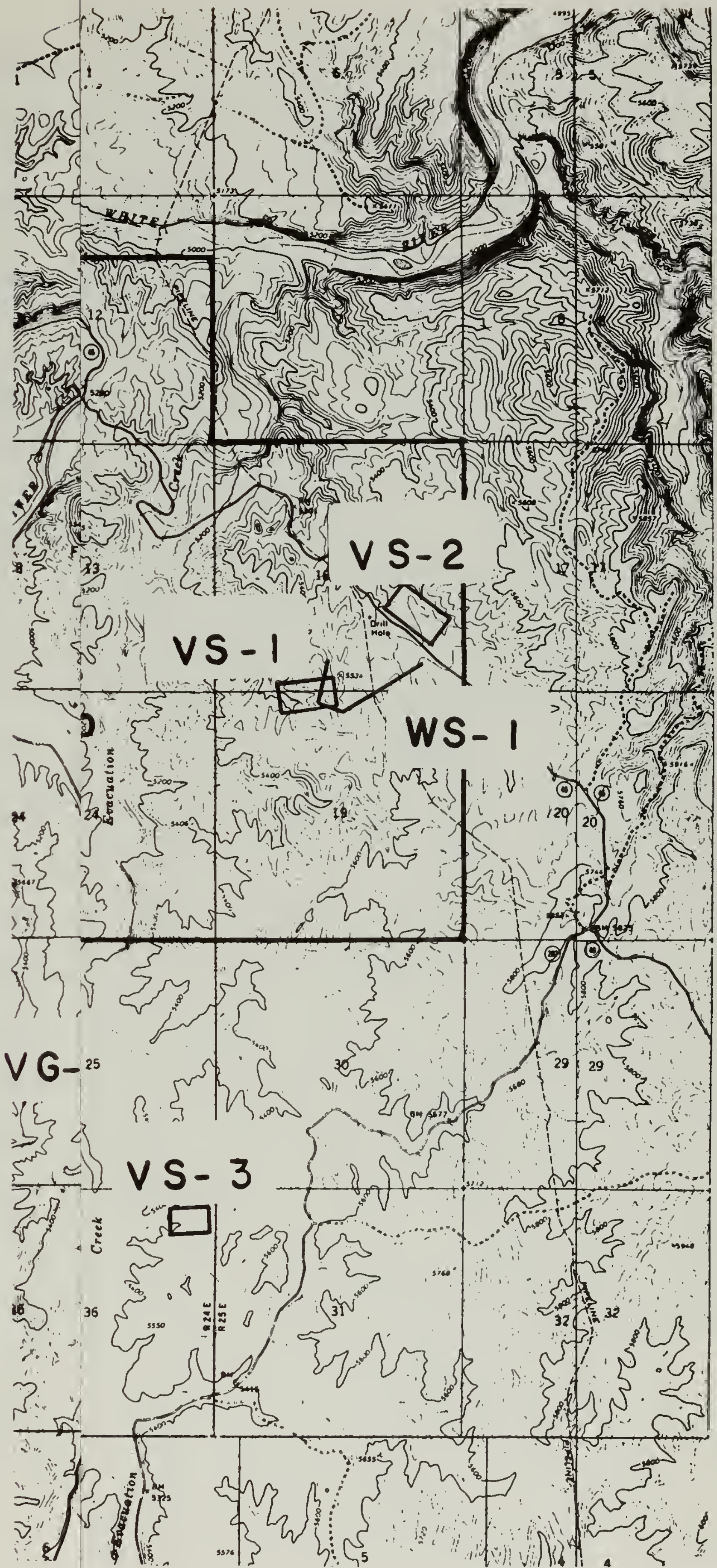
4.3.1.1 Objectives. The major objectives of the vegetation monitoring program are to maintain continuity of key parameter data collection, determine trends, develop supportive vegetation data for animal monitoring results, and to explore the "control" versus "treatment" system of monitoring oil shale development impacts. The last objective holds the promise of factoring out natural cyclic trends while determining true net impacts of development operations.

4.3.1.2 Methods. During the period of Interim monitoring the task of monitoring vegetation consist of the following:

FIGURE 45

VEGETATION/VERTEBRATES

MONITORING SITES



LEGEND

☐ = VEGETATION - GREASEWOOD
JUNIPER
SHADSCALE

= WILDLIFE

⊙ = VEGETATION - SAGEBRUSH

UTAH

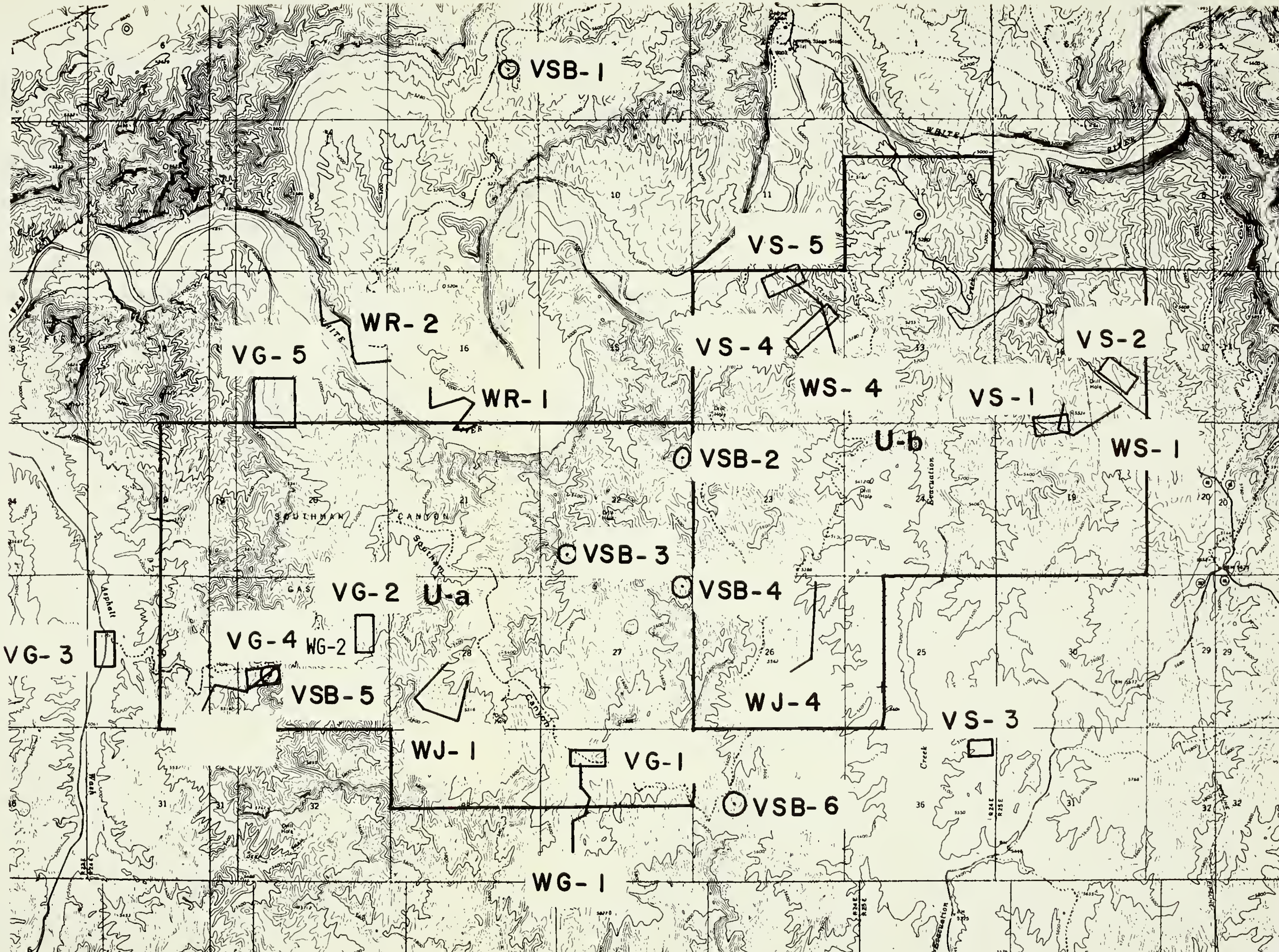
N

1 0 1

SCALE IN MILES

FIGURE 45

VEGETATION/VERTEBRATES MONITORING SITES



LEGEND

□ = VEGETATION - GREASEWOOD JUNIPER SHADSCALE

/\/ = WILDLIFE

⊙ = VEGETATION - SAGEBRUSH

1 0 1

SCALE IN MILES

A. Measurement of productivity of annual plant species.

B. Measurement of leader growth of big sagebrush, a dominant shrub on Tract Ua/Ub.

C. Measurement of percent of stems browsed on shrubs measured in B.

D. Performance of visual surveys of general nature in regard to vegetation conditions, including:

- seed production
- seedling establishment
- animal utilization
- any unusual buildup of insects or plant disease or early seasonal dormancy.

At the peak of annual growth in the spring (June) annual species are clipped from approximately 200 .5 m^2 plots in areas previously sampled during the Baseline study located in the sagebrush/greasewood vegetation type and the shadscale/sagebrush type. Sampling is done in the same manner as in the Baseline inventory. Three areas in Section 22 are included in the sampling for productivity of annual plants. These areas correspond to the sagebrush stem growth transects. Sampling of the juniper type may be necessary but will depend upon the favorability of the growing season.

In the fall (September-October) current year's stem growth of big sagebrush is measured in a paired-plot arrangement on an adequate number of sagebrush plants along three transects in the zone of influence of the proposed industrial site (in Section 22) and on three transects in areas surrounding that site. This will allow a comparison of stem growth in and around the proposed industrial site and in surrounding areas.

During the time of productivity sampling in the spring and the measurement of stem growth in the fall, an ocular reconnaisance of vegetation conditions on the tract is made. Reproduction, plant growth and vigor, and any excess animal utilization is noted. Quantitative data

is obtained to validate any visual observations as required. Observations of vegetation condition is also conducted as an ongoing activity during revegetation study.

4.3.1.3 Data Summary. Weather during the fall and winter of 1976-77 was unusually dry. This drought was so intense and with long periods during which no precipitation occurred that germination of annual plants such as downybrome or cheatgrass (*Bromus tectorum*) russian thistle (*Salsola kali*) lamb's quarters (*Chenopodium album*) and Bassia (*Bassia hysopifolia*) did not occur. The rainfall record for the research site in Section 6 north of the White River gives evidence of the extreme drought in the fall and winter (Table 38). Not until late April did any effective precipitation occur but the subsequent dry period precluded any chances for growth of annual except for a very few isolated plants in protected places.

Consequently, the growth of perennial forbs and shrubs in the spring months appeared to be severly restricted by the lack of winter precipitation and a very dry soil profile.

On June 10 and 11 of 1977 all vegetation study locations utilized previously in the Baseline Monitoring Program were visited. With the exception of the two Riparian sites in the floodplain of the White River, there was essentially no annual or herbaceous vegetation to harvest for biomass estimation. Occasionally a lone plant of cheatgrass was observed under the protective canopy of a shrub but there was not enough to clip. In some areas of disturbed soils, Russian thistle was just getting established in response to the late April - early May storms. Therefore, only plots in the two locations on the White River floodplain were sampled

TABLE 38. Precipitation for the Bonanza, Utah area 1976-77 growing season.

Date	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1					.03							
2				T	.62							
3												
4										.30		
5												
6												
7												
8												
9									.04			
10			T									
11												
12							.51					
13												
14												
15												.68
16								.27				
17											.70	
18												
19							.62					
20												
21												
22				.20								
23				.10								
24												
25										.88	.52	
26												
27												
28							.17					
29												
30												
31						.77		.10				
Total	.10	0	T	.30	.65	.77	1.30	.37	.04	1.18	1.22	.68

Total 6.61

(clipped) for biomass determinations, all other sites were observed, notes were taken on the condition of the vegetation and a photograph was made.

A. Biomass Sampling

The following observations and photographs are provided in lieu of biomass sampling which would have yielded little, if any, useful data (Figures 46-64). Only in the two riverbottom study sites were any vegetation plots clipped.

B. Sagebrush Stem Growth

1. Concept of Stem Growth as an Index of Site Conditions

During the Baseline study many vegetation characteristics were measured and monitored. Some of these characteristics such as shrub height and density do not change rapidly nor is it their nature to clearly reflect the effects of short term environmental conditions. Individual shrub height may reflect an overall increase due to the growth of stem tips but when considered as a plant community characteristic, height is a parameter that remains nearly constant.

A vegetation measurement was needed that would reflect site conditions, especially unfavorable conditions. If such a measurement could be found that reflected growing conditions, it would be useful as an index and could serve to indicate the occurrence of an adverse environmental impact from development. At the same time such an index would be invaluable as an indicator of unfavorable weather conditions and not place the blame on oil shale developments.

Sagebrush stem tip growth appears to have the characteristics of a good site favorability index. Extensive field experience indicates that sagebrush stems grow much longer in years of favorable precipitation and

temperature than in drought years. Even so there are differences among populations in stem growth each year that must be studied in order to use stem length as an index. It is also important that sagebrush stem growth be characterized before development in order to provide baseline or comparative information.

2. Methods Used for Measurement

Stem measurements are easily made and can be done rapidly thus providing for large numbers of observations. In the present monitoring effort, twenty stems per plant and twenty plants in six different sites were measured for a total of 2400 observations. The general plan for measuring sagebrush stems in a Baseline program was to measure two sagebrush populations in the close vicinity of the proposed industrial mining site (Section 22) and compare results with populations in four directions at least 2 miles distant (according to study plan submitted for Interim monitoring period).

To make a measurement a two to three year old branch was clipped from a sagebrush plant. The longest current year's stem was measured with a millimeter ruler from the bud-scale scar to the tip of the stem, including leaves at the tip. Since the bud scale scars in sagebrush are clear to see and indicate the location from which growth was initiated at the beginning of the growing season, the measurement is objective and free of bias.

3. Sagebrush Stem Growth for 1977

All sagebrush stems were very short in 1977 (Table 39). Except for the sagebrush plants in the Asphalt Wash area, most stems averaged a

TABLE 39. Average sagebrush stem growth and standard deviation in 1977 on six selected sites of the prototype oil shale lease tracts U-a and U-b. Each value is the mean of 20 observations from an individual plant.

Plant No.	Site 1 Near development site Sect 22		Site 2 Near development site Sect 22		Site 3 West of Industrial Site Asphalt Wash Sect 29		Site 4 South of Industrial Site Sect 35		Site 5 East of Ind. Site Sect 18		Site 6 North of Industrial Site Sect 3	
	Mean length cm	SD	Mean length cm	SD	Mean length cm	SD	Mean length cm	SD	Mean length cm	SD	Mean length cm	SD
1	2.13	.26	2.23	.20	3.94	.55	2.15	.21	1.80	.22	2.73	.29
2	1.99	.23	1.53	.22	5.15	.13	2.54	.20	3.03	.84	2.75	.23
3	2.61	.29	2.22	.34	5.22	2.00	2.29	.60	3.00	.41	2.84	.49
4	2.15	.38	2.69	.88	4.15	.48	2.23	.21	3.55	1.21	3.14	.67
5	1.75	.02	1.99	.11	3.07	.48	2.04	.06	2.48	.22	2.52	.25
6	2.01	.12	2.05	.36	4.65	1.42	2.23	.11	2.42	.20	4.26	1.47
7	1.54	.13	2.63	.39	4.33	.89	1.91	.29	2.04	.24	2.42	2.31
8	2.17	.21	2.46	.19	4.75	1.28	1.94	.16	2.07	.16	3.40	.34
9	8.31	1.06	2.52	.84	2.64	.53	2.50	.45	3.18	.90	3.72	.95
10	1.40	.18	3.62	.48	3.73	.66	2.74	.56	2.63	.36	2.28	.33
11	2.55	.25	1.57	.82	4.29	.99	2.72	.38	3.07	.61	2.70	.24
12	1.81	.16	2.68	.51	3.27	.66	1.99	.15	3.36	.46	2.15	.14
13	2.64	.50	2.18	.13	4.79	.76	1.91	.15	3.14	.31	2.31	.41
14	1.90	.21	1.71	.14	4.04	1.09	2.22	.61	2.28	.33	2.23	.35
15	1.91	.29	1.67	.03	5.06	2.10	2.22	.21	3.77	1.96	2.65	.41
16	1.56	.10	2.20	.41	4.23	.85	2.29	.21	2.24	.09	3.15	.71
17	1.65	.32	1.57	.02	3.31	.59	1.65	.15	3.06	1.41	2.67	.29
18	1.61	.22	1.55	.08	4.12	.99	2.40	.04	2.58	.36	2.40	.54
19	1.81	.12	1.78	.33	2.88	3.40	1.95	.11	2.72	.59	2.62	.51
20	2.02	.10	2.11	.10	3.18	.48	1.59	.16	3.14	.91	2.68	.33
Mean	2.03	.25	2.14	.32	4.04	1.02	2.18	.25	2.78	.59	2.81	.56

little more than 2 cm. The variability was generally low with a standard deviation of between .25 and .59 cm. The sagebrush plants in Asphalt Wash appeared to have produced most of their new stem growth in the late fall rather than during the summer. This was evident by the succlent, flexible nature of the new stems as compared with the short relatively stout stems with tightly packed leaves observed on other sites.

The short stems observed in 1977 could have been predicted on the basis of the rainfall pattern and total amount during the late winter and growing season. This limited growth response matches the observed lack of germination and growth of annual understory grasses and forbs.

4. Comparison of Stem Growth in 1977 with Previous Years

A comparison of sagebrush stem growth measurements made in 1977 with those reported for 1976 and 1975 further emphasize the favorable growing conditions for 1977 (Table 40) and the fidelity with which sagebrush stem growth reflects seasonal differences in growing conditions. In 1975 the rainfall distribution pattern in the spring and summer months was very favorable for plant growth. Sagebrush twig length reflected this favorability with an average length of 7.03 cm.

In 1976 plant growth was considerably less due to a relatively dry early spring period and reduced summer storms frequency. The average stem growth in 1976 was 5.9 cm. In 1977, the region experienced one of the most severe droughts since the mid 1930's, and average sagebrush stem growth on Tract Ua/Ub was only 2.55 cm.

The relative growth differences at the various sites did not change over the three year period. Sagebrush plants at the Asphalt Wash site consistently produced longer stems than the other sites even in a dry year.

TABLE 40. A comparison of sagebrush stem growth in 1977, 1976 and 1975 at six sites on oil shale prototype lease tracts U-a and U-b.[1/]

Site of Measurement Site No. Description		Year of Measurement 1975 mean length cm	1975 SD	1976 mean length cm	1976 SD	1977 mean length cm	1977 SD
1.	Industrial site-Sect. 22 G-22	7.39	2.14	6.2	1.04	2.14	.35
2.	Industrial site-Sect. 22 G-5	6.96	1.12	6.16	1.63	2.03	.25
3.	Section 29-3 miles west of industrial site Asphalt Wash	9.69	1.86	7.0	.88	4.04	1.02
4.	Section 35-South of Industrial Site	5.60	1.03	5.5	1.06	2.18	.25
5.	Section 18-3 miles East of Industrial Site	7.15	1.31	5.4	1.17	2.78	.59
6.	Section 3-3 miles No. of Industrial Site	5.37	1.5	4.8	1.08	2.81	.56
	Overall Average	7.03		5.9		2.55	

1/ Each value is the mean length of 20 stems on 20 plants for a total of 400 observations.

The two monitoring sites 1 and 2 are within the area of influence of the proposed industrial site in Section 22. Both of these populations were relatively similar in their stem growth and degree of variability.

C. Summary and Conclusions

Plant productivity and sagebrush growth on the prototype oil shale lease tracts in 1977 was very limited. The normal germination of annual plants such as Bromus Tectorum failed to occur because of a very dry fall, winter and early spring. In the sagebrush-greasewood vegetation type where the production of annual species was 51.1 g/m^2 in 1975 and 20.92 g/m^2 in 1976 there was not enough to harvest in 1977.

A photo reconnaisance (see Figures 46-64) of the areas studied during the Interim period graphically shows the dearth of vegetative cover. Only the late germinating annual weeds, russian thistle and halogeton yielded any production of annual biomass in 1977.

Growth of perennial species of shrubs and forbs was also very limited in 1977. Measurements of sagebrush stems indicated that the length of new growth was only 43 percent as much as in 1976 and only 36 percent as much as in 1977.

From three years of experience with sagebrush stem growth measurements, it appears to be an excellent index of the favorability for plant growth.

A. Saltbush - Sabebrush vegetation type (V = vegetation
S = saltbush)

1. Location VS-1 (Figure 46)

No downy bromegrass evident in this area. A trace of immature annual mustard plants were seen. New seedlings (less than 1.5 mm high) of Russian thistle and halogeton were seen under the protection of shrubs where they constituted 5-10% cover. Occasional plants of the perennial grass, *Hillaria jamesii*, were noted to have a few green leaves but the degree of growth was very limited.

Figure 46. Appearance of bare ground and shrubs in June 1977.

2. Location VS-2 (Figure 47)

Here there is much evidence of old downy bromegrass litter from previous years. Because of dry fall and winter season limited decomposition of litter has occurred. Very few scattered plants of bromegrass but about 5% cover of small Russian thistle plants. The stunted bromegrass plants (2 cm high) looked as if they were too small and immature to produce a seed crop.

Shrub utilization by animals is extremely high. Some shrub stems are utilized back to old woody stems.

Figure 47. View of saltbush vegetation showing bare ground in interspace area.

3. Location VS-3 (Figure 48)

Growth of russian thistle in litter from previous year's vegetation is evident in areas where some protection is available. Such small plants appear to have germinated after rainstorm in late April and May.

Figure 48. Seedling of Russian thistle in old litter cover.

4. Location VS-4 (Figure 49)

This site is on the breaks to the south of the White river. Here shrubs have had intense grazing. Space between shrubs is bare except for old litter and in areas of deeper soils the perennial grass clumps are severely grazed.

Figure 49. Mixed shrub community. Note shadscale plants in background. Shrub to the left of plot from has been hedged back to old growth.

5. Location VS-5 (Figure 50)

In this area of the shadscale vegetation type on the breaks south of the White River, stands of the perennial grass, *Hillaria jamesii* exist on heavy soils. These grass plants have been grazed down severely. Litter cover is evident.

Figure 50. An area of *Hillaria jamesii* included in a shadscale plant community. Note grazed appearance of grasses and absence of substantial new growth.

B. Greasewood - Sagebrush Vegetation Type

1. Location VS-1 (Figure 51)

Bareground in interspaces between shrubs is devoid of annual plants except for occasional russian thistle. Litter from previous year is evident and has not decomposed to any significant degree.

Figure 51. Bareground in interspaces between shrubs is extensive. Undecomposed old litter remains as a soil surface cover.

2. Location VS-2 (Figure 52)

The open spaces between sagebrush and greasewood shrubs normally support a stand of annual plants. In this site only an occasional stunted annual plant may be found.

Figure 52. Occasional growth of downy brome (cheatgrass) occurs when some moisture was available for germination. Maturity to the seed production stage is doubtful.

3. Location VG-3 (Figure 53)

In this study area located in the bottom of asphalt wash the drought appears to be most severe. Rabbits and other small mammals have been forced to turn to the stems of greasewood for food and possibly moisutre. No seedlings of downy brome or Russian thistle were found in spite of a protective litter soil cover.

Figure 53. Appearance of greasewood stems after rabbit and small rodent gnawing on them.

4. Location VS-4 (Figure 54)

Intense browsing of sagebrush back to old woody stems is evident in most areas of the tracts. Not all plants are browsed to the same degree, an indication of the palatability differences that exist in shrub populations.

Figure 54. Intense browsing on one sagebrush plant as contrasted with limited browsing on another one.

5. Location VG-5 (Figure 55)

Sagebrush and greasewood often occupy sites of higher production potential than shadscale or juniper sites. Evidence of this potential is indicated by abundant undecomposed litter from previous years growth. No annual species were found in this immediate area. Shrub growth was very limited compared with that observed at this season in previous years.

Figure 55. Sagebrush and greasewood plants with abundant litter from previous year but no new seedlings at the present time, June 1977.

C. Juniper Vegetation Type

1. Location VJ-1 (Figure 56)

Large open areas and bare ground are typical of the Juniper vegetation type on the oil shale tracts. Shrubs and perennial forbs such as Utah sweet vetch (*Hedysarum boreale*) have been intensly grazed.

Figure 56. Open spaces and intense utilization of shrubs and palatible forbs characterize the juniper vegetation type.

2. Location VJ-2 (Figure 57)

The soil surface under the juniper trees is covered with old litter from previous years. Normally, old juniper litter is slow to decompose (has an acid pH). Juniper stems require years to decompose.

Figure 57. Bareground and old litter characterize the Juniper vegetation type. Intense utilization of shrubs is evident in 1977.

3. Location VJ-3 (Figure 58)

Normally, the amount of understory vegetation is a juniper is minimal. In 1977 no annual species were found. Shrubs were intensely hedged back to old growth.

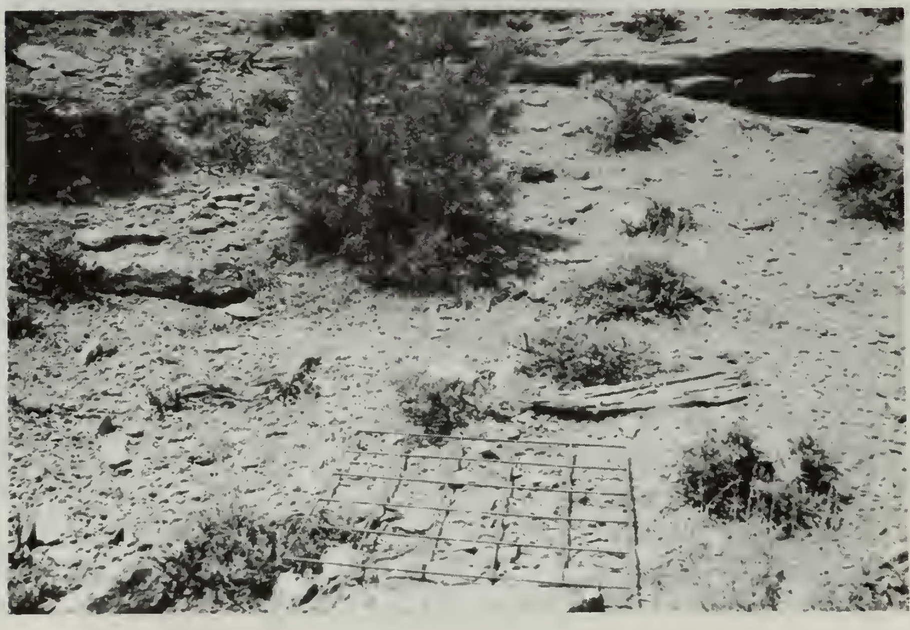


Figure 58. A typical juniper site. Note shallow soil over the sandstone parent material. Shrubs have been browsed to old wood.

4. Location VJ-4 (Figure 59)

Intense grazing of *Artemisia Parryii* is seen in this view of a juniper-dominated plant community. No annual vegetation was found in the interspaces even though the direct juniper influence was at a distance.

Figure 59. *Artemisia parryii* receives intense grazing in a drought year. No annual vegetation was present.

5. Location VJ-5 (Figure 60)

Juniper trees have long been valued for their resistance to decay and have thus found use as fence posts. Here a juniper tree was cut and trimmed out for posts just a few weeks prior to the June monitoring period. Public use (and abuse) of the general region appears to be unabated in spite of the care being taken to study the area and make plans for maintaining its environmental quality.

Figure 60. Remains of a juniper tree filled for use as a juniper post.

D. Riparian Vegetation Type

1. Location VR-1 (Figure 61)

Large grassy openings among the *Populus angustifolia* overstory indicate the high productivity of the riparian sites along the White river. Average production in 1977 was only 4 percent that of 1975 and 80 percent that of 1976 (Table 41)

Figure 61. Open park-like appearance of the grass and tree riparian vegetation.

Table 41. Harvest weights from ten .25 m^2 plots

Clipped on June 10, 1977. Riparian Site 1 and 2

	Plot No	Wt (g)
VR-1	1	6.5
	2	8.2
	3	7.9
	4	6.1
	5	5.4
	6	1.1
	7	3.0
	8	2.1
	9	7.3
	10	5.9

		1975	1976
Σ	= 51.5		
$\bar{x}$	= 5.15 g/.25 m^2 = 20.60 g/m^2	533.25	25.23
S.D.	= 2.47		

Species Observed

Poplar	*Populus angustifolia*
Western wheatgrass	*Agropyron Smithii*
Saltgrass	*Distichlis stricta*
Alkali sacaton	*Sporobolus cryptandrus*
downy brome (cheatgrass)	*Bromus tectorum*
Yellow mustard	*Sissymbrium altissimum*
Lamb's quarters	*Chenopodium album*
bee flower	*Cleome lutea*
greasewood	*Sarcobatus vermiculatus*

2. Location VR-2 (Figure 62)

The grassy understory vegetation in the riparian type varies tremendously from year to year in production. Grass density in 1977 in the river bottom was open with considerable litter carry over from previous years.

Figure 62. Grass height is less than eight inches and few tillers are present. Old leaves from the poplar trees remain from 1976. Harvest yields were less than other years.

3. Location VR-3 (Figure 63)

In contrast with 1975 or 1976 this site was very dry and supported a meager stand of annual species. The tamarix and willows had many dead stems that were alive in earlier years. Salt grass was the dominant species in 1977 as contrasted with yellow blossom sweet cover in 1975-76. A few annual species were recorded however.

Figure 63. Willow and tamarix clumps with a grass-forb understory in a riparian vegetation site on the south side of the White river.

4. Location VR-4 and 5 (Figure 64)

Vegetation growth in this more xeric site of the riparian vegetation type was very limited in 1977. Old litter under the canopy of shrubs contained (or protected) a few seedlings of Russian thistle and downy brome. The soil was too dry to sustain the growth of annuals to maturity (without further rainfall in July and subsequent months). Biomass sampling was not feasible on these two sites.

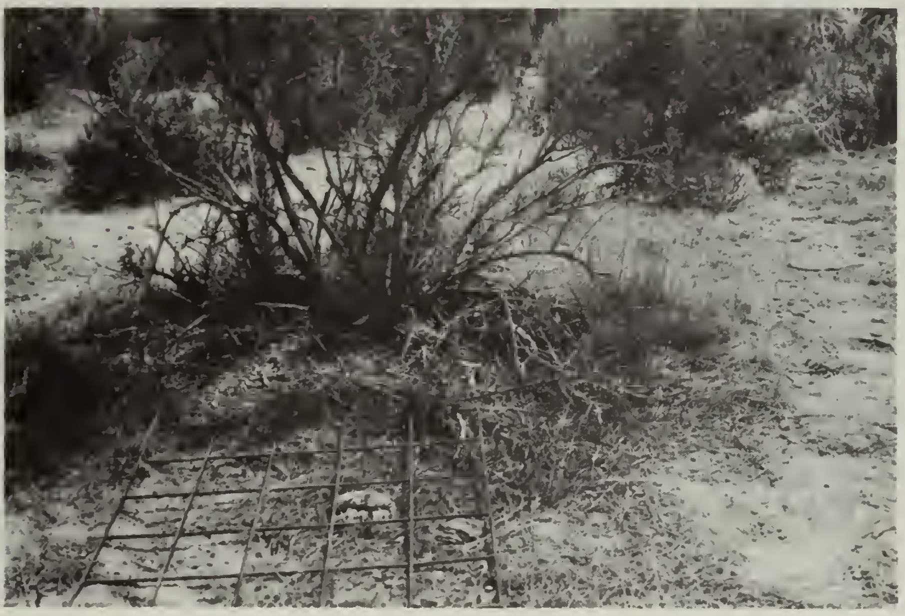


Figure 64. A xeric riparian site in the bottom of evacuation creek. Note abundant litter under the naked canopy of the greasewood bush.

4.3.2 Terrestrial Biology

Terrestrial vertebrates, amphibians, reptiles, birds, and mammals have been monitored for the past three years on the Utah Oil Shale Tract Ua/Ub. During the Interim Monitoring Program, beginning in December 1976 and ending in December 1977, three hypotheses concerning the vertebrates have been tested: 1) mammal populations have reached a peak and will decline; 2) bird populations are in a downward trend and will continue to decline; and 3) reptile populations will remain stable. To test these hypotheses, five criteria established in the two-year Environmental Baseline Monitoring Program have been used:

1) species inventory;
2) species distribution within habitat types;
3) species distribution within seasons of the year;
4) species abundance and density; and
5) ecological relationships of vertebrates to their biotic and abiotic environment.

Bio Resources Inc. performed the work described in the following sections.

4.3.2.1 Objectives. The primary objective of the program is to extend the data base on terrestrial vertebrates to allow analysis of population trends noted during the Baseline period. A secondary objective is to evaluate control-treatment monitoring techniques which would allow for distinguishing directly between natural cyclic changes and changes attributable to oil shale development activities.

4.3.2.2 Methods. The Utah Oil Shale Tracts are located in the Uintah Basin of northeastern Utah. The tracts cover sixteen square

miles comprised primarily of arid land, including small section of the White River on the tracts' northern boundary (Figure 65, map of area including Vernal).

Vertebrate sampling was keyed to four vegetation associations found on the tract: 1) sagebrush-greasewood; 2) juniper; 3) shadscale; and 4) riparian (Figure 66). Sagebrush-greasewood associations were found primarily in Southam Canyon, Asphalt Wash, and in small side canyons leading into Evacuation Creek and the White River. Juniper associations were found in the uplands in and to the east and west of Southam Canyon. Shadscale associations were found west of Evacuation Creek, covering most of Tract Ub. Riparian associations were found on the White River and Evacuation Creek. Detailed studies of these associations are in the Final Environmental Baseline Report (Anon., 1977).

Two vertebrate sampling sites were placed in each vegetation association to study spatial distribution (Figure 67). Vetebrates were sampled for two weeks in February, April, June, and August to study temporal distribution. To determine abundance and density, techniques particular to the different vertebrates were carried out at each sampling site. Vertebrate identifications were made during each sampling period to establish an inventory.

Mammals

Four techniques were used to study the mammals: 1) flushing transects; 2) trapping; 3) mist netting; and 4) a large mammal aerial survey.

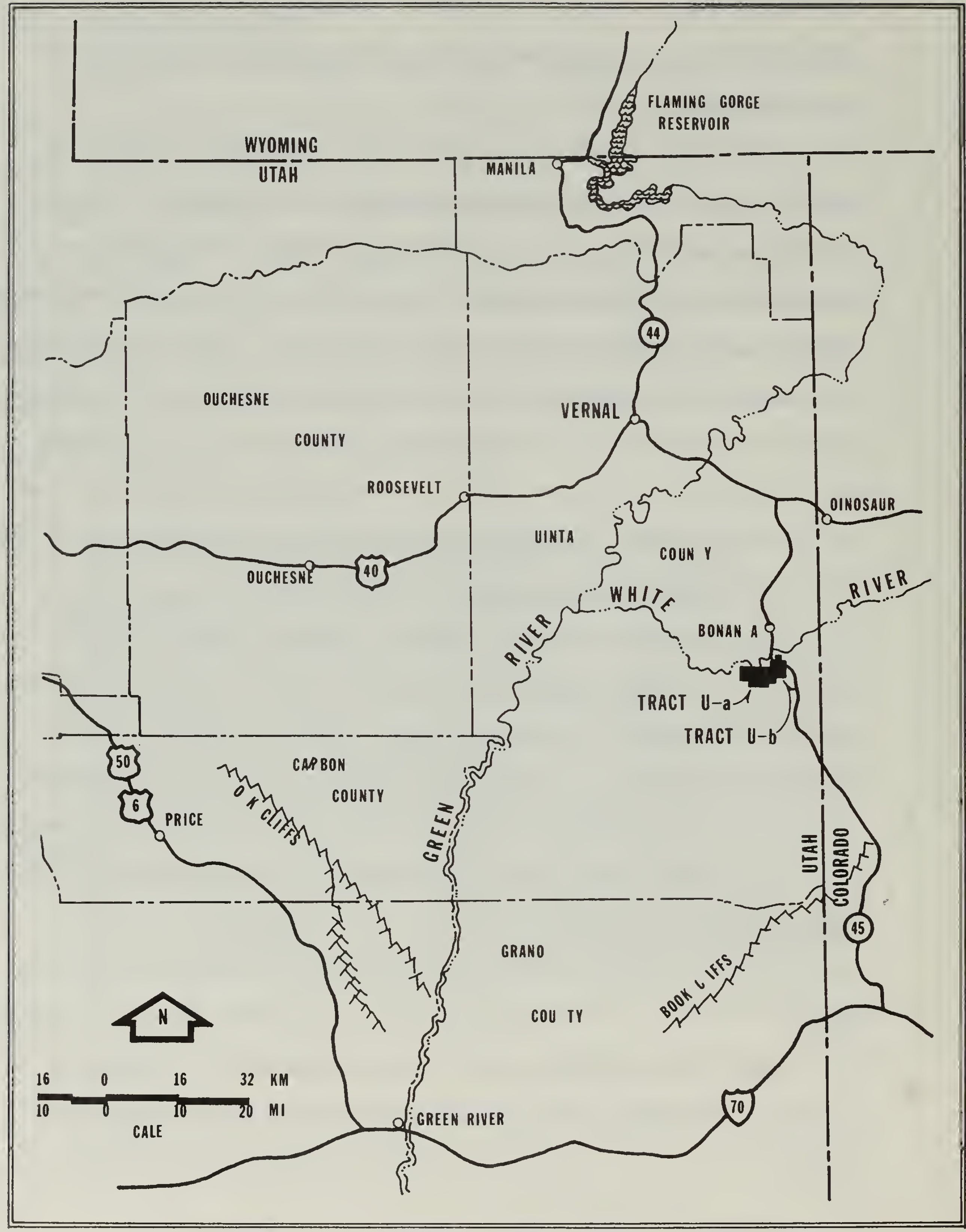


Figure 65. General location of the Utah Oil Shale Tracts, Ua and Ub, in northeastern Utah (After map by VTN, Inc., 1977).

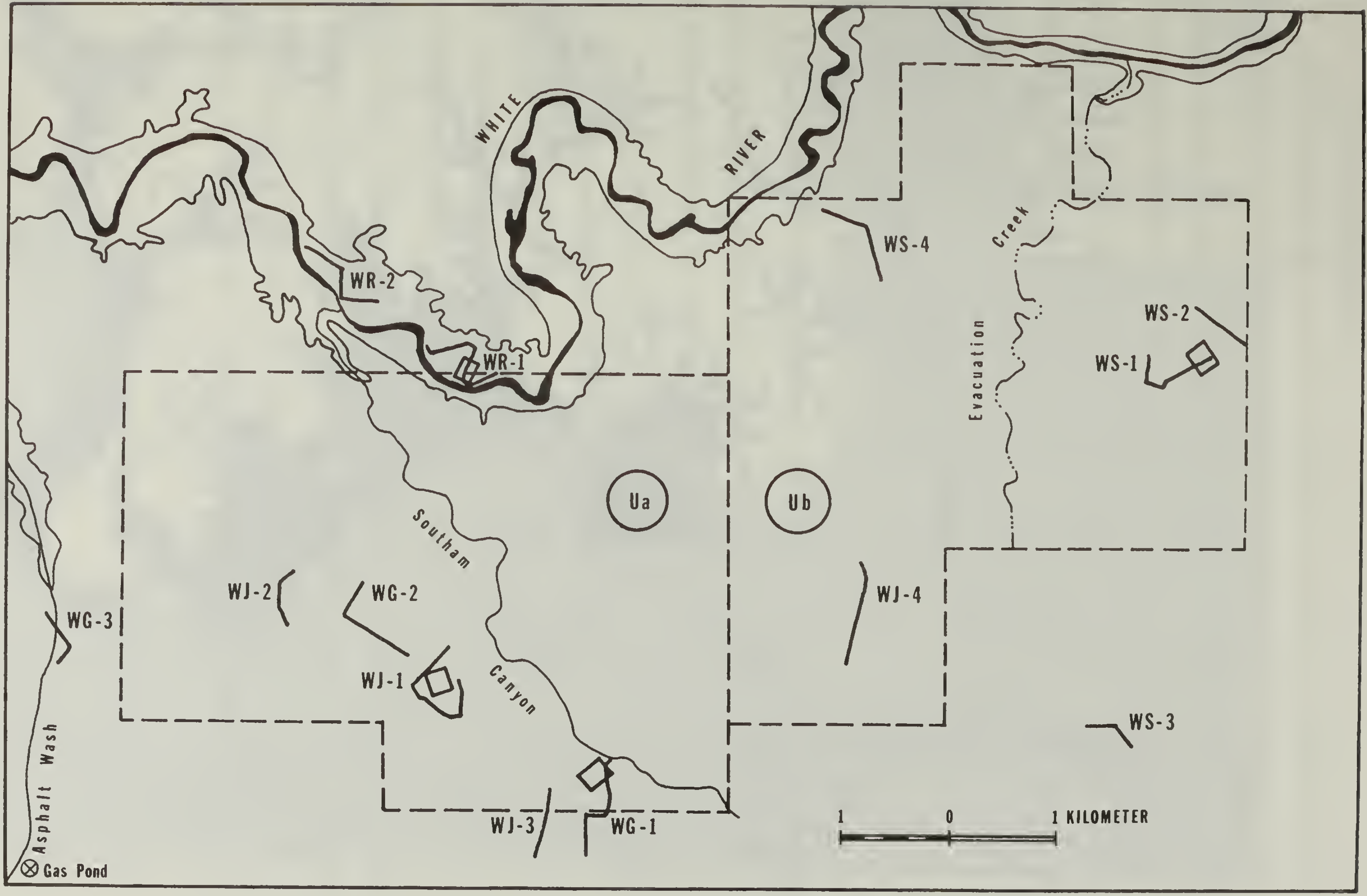


Figure 66. Location of flushing transects, large rodent traps, and mist-netting site used for terrestrial vertebrate monitoring on the Utah Oil Shale Tracts.

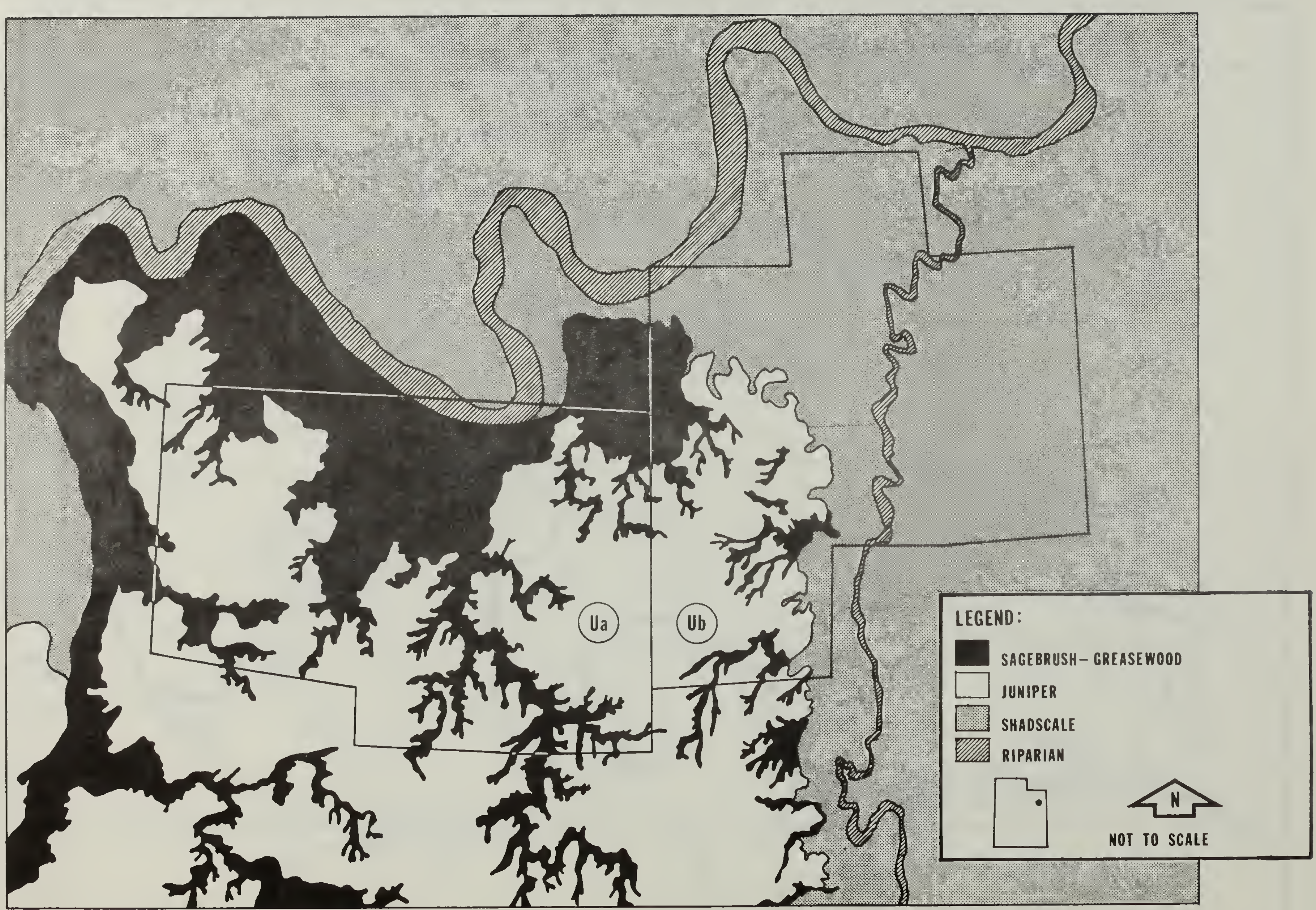


Figure 67. Vegetation types on the Utah Oil Shale Tracts (After map by VTN, Inc., 1977).

a. Flushing Transects

One flushing transect, one kilometer in length, was established at each sampling site. Configuration of the eight transects was based upon topographical necessity. Each bend in a transect was marked with a metal fence post and the transect line was marked with flagging in between posts. Each transect was walked for five consecutive days. Four transects were walked each evening during a 2.5 hour span, beginning two hours prior to sunset and concluding one-half hour after sunset. Data recorded for each transect were time and date, weather conditions, species observed and heard, including sign (tracks, scats, etc.), number of individuals observed, and individual's perpendicular distance (meters) from the transect line, some behavioral characteristics (feeding, drinking, mating, stationary, moving, etc.), and habitat use (open ground, brush, tree, rock, etc.). All data were key-punched for storage and analysis.

Mammalian identification followed Armstrong, 1972; Burt and Grossenheider, 1964; Durrant, 1952; Murie, 1975; Olsen, 1973; and Ranck, 1961. Densities from flushing transect observations were not calculated (Anon., 1977). Instead, abundance was determined by summing the individuals observed during each sampling period. These data were used to assess trends for 1977 and to compare abundance for the same sampling periods for 1975 and 1976 (Anon., 1977). Comparisons were made according to mammalian abundance by vegetation type, by seasons and by years using the Analysis of Variance and appropriate techniques for ranking means (Steele and Torrie, 1960).

Differences in transect methodology made in 1977 compared to 1975 and 1976 were as follows:

1) Transects WR-1, WR-2, and WG-2 were each extended to 1 km in length.

2) Transects WJ-2 and WS-2 were replaced by transects WJ-4 and WS-4, respectively.

3) None of the transects in the 1 mile boundary area around the tract were used in 1977, with the exception of WR-2.

4) Distance walked on transects was 40 km/sampling period compared to 27.5 km/sampling period in 1975 and 1976.

5) Sampling periods were two weeks in duration in 1977 and three weeks in 1975 and 1976.

6) December and October samples were not made.

The specific transect locations (Figure 67) were designed primarily to allow for adequate coverage of Tract Ua/Ub in extending the Baseline data. Secondarily, some locations can be designated as control-treatment sites during shale processing. Two transects in Southam Canyon (WG-1 and WJ-1), the area designated for spent shale disposal, will monitor changes within the treatment area. Two other transects, WJ-4 to the east and WG-2 to the west of Southam Canyon, will be control sites. No activities are planned in the former area throughout Tract Ua/Ub development, and WG-2 will not be impacted until quite some time into the development period. WS-1 can be considered a control site in the shadscale vegetation since it is some distance from any site of planned activity. WS-4 near Ignatio Stage Stop can be used as a site to monitor changes due to vehicular traffic during construction and processing.

b. Trapping

A 165 x 165 m trap grid was set in each vegetation type during the August sampling period. One hundred forty-four Sherman live traps were

set in a 12 x 12 array, 15 m between each trap. Each area (WG-1, WJ-1, WS-1, and WR-1, Figure 67) was trapped for five consecutive nights. Traps were opened and baited with rolled oats prior to sunset, then checked, emptied, and closed the next morning. Size of the traps was 23 x 9 x 7.7 cm.

A captured mammal was identified to species, aged (juvenile or adult), sexed, weighed using 100 g and 500 g capacity Pesola scales, marked individually by toe clipping, and released. Capture and recapture locations were recorded, as were physical condition (pregnant, torpor, diseased) and other occurrences (double and triple capture in one trap, number of snapped traps).

Densities were calculated according to the formula D = n/a, where:

D = density (number/hectare)

n = number of individuals captured

a = area covered by trap grid (2.72 ha).

The use of this simple formula was based upon Anderson's (1975) findings in the Curlew Valley of northern Utah.

Movement within a trap grid was calculated for each individual captured two or more times. The straight line distance (meters) between each trap station was used in lieu of home range estimates (Jennrich and Turner, 1969) due to constraints inherent in the home range formula. Movement data were compared to 1975 and 1976 information for the same grids, as were density estimated (Anon., 1977).

Small trap grids were set straddling each transect during the February, April, June and August sampling periods. Twenty-five Sherman live traps were set in a 5 x 5 array, 15 m between traps, covering 0.36 ha. All procedures and calculations were identical to those used in the large trap grids.

Differences in trapping methodology made in 1977 compared to 1975 and 1976 were as follows:

1) The riparian trap grid was enlarged to 165 x 165 m, using 144 trap stations. In 1975 and 1976, it was 75 x 165 m, 72 trap stations.
2) Small trap grids were set in a 5 x 5 array each sampling period, compared to a 2 x 12 array in 1975 and 1976.
3) All rodents captured in the small grid during 1977 were marked for individual identification, whereas in 1975 and 1976 rodents captured were not individually marked.
4) Trap mortality was reduced by heavily baiting each trap during February and April.
5) All rodents captured were weighed.

c. Mist Netting

The bat sampling program for 1976 was carried out at five separate sites. During May 1976, two sample nights were spent on the banks of the White River at Ignatio Stage Stop and at sampling site WR-2, and one night at Asphalt Wash gas pond (see below for description). The mist netting effort during August, 1976, was conducted for one night on the sandbars and channels of the White River near sampling site WR-1, one night at a stock-watering pond north of Bonanza, Utah, and three nights at the gas pond in Asphalt Wash (see Figure 67 for site locations).

Because of the previous, consistent capture success, the gas pond in Asphalt Wash was the site of all mist netting activities during the 1977 sampling season.

The gas pond is located approximately 0.5 road miles north of the confluence of the west and center forks of Asphalt Wash; T11S, R24E, Sec. 6. The area surrounding the gas pond has numerous small caves, deep overhangs, and faults, in addition to extensive greasewood stands. The water in the gas pond has a constant replenishment apparently from the Bird's Nest aquifer (Anon., 1977). The gas pond is approximately 50 feet in length, 25 feet in width, with an oval configuration. It is lined with cattails and bullrushes and closely surrounded by a greasewood stand. The area has an abundance of flying insects, e.g., Dipterans and Coleopterans.

During the 1977 sampling season, mist nets were positioned on May 31 and Aguust 15, in a fashion that conformed to the 1976 netting effort. The nets were left in position throughout each sampling period, but were rolled up at the end of each night to avoid accidental avian and chiropteran captures. Sampling began each night at approximately 8:00 P.M. (2000 hours), or one hour before dark, and continued until 12:00 P.M. (2400 hours) usually, and as late at 0300 hours. No early morning (predawn) sampling was done. The sampling crew consisted of a minimum of two and maximum of four biologists checking the nets on a fifteen-minute rotation. When multiple captures occurred, the bats were all positively identified prior to removal to prevent a complete loss of data should escape result. During 1977, each bat captured was identified to species, sexed, weighed (August), and measured for length of hind foot, forearm and tragus. Each bat was given a temporary mark to identify recaptures. In June 1977 a spot of nail polish was put on the thumb and a spot on the dorsal surface of the neck. In August 1977 toenails were clipped to identify individuals. Handling was kept to a minimum to prevent undue shock to the captured animals. Bats that were wetted

during the exercise were dryed as quickly as possible and released. Identification was based upon Barbour and Davis (1969) and Burt and Grossenheider (1964).

Data taken on-site were kept in field notebooks and later transferred to computer forms. In August 1977 computer forms were filled out as bats were captured and measured.

d. Large Mammal Aerial Survey

A large mammal aerial survey had originally been scheduled for December 1976. Due to weather conditions, i.e., no snow cover during the month, the survey was postponed. A later attempt in January 1977 was ineffective because of limited snow cover.

Snow cover is vital to an aerial survey because of increased visibility of the large mammals. The Uintah Basin does not have a highly predictable winter weather pattern and, as a result, aerial surveys cannot be replicated from year to year. A sampling technique that cannot be conducted at a specific time, for a specific duration, and with a specific intensity is unreliable. There can be a definite similarity from different sampling time but, no matter what the results, a definite difference. One objective of the monitoring program has been reliability of information. To utilize the large mammal aerial survey with its limitations would render the objective impossible to reach. Therefore, discontinuation of the survey for future years is recommended.

Birds

a. Flushing Transects

The same sampling periods, sampling sites, procedures, calculations, and comparisons used on mammal transects were used for birds, with one

exception. Bird transects were walked between sunrise and three and one-half hours after sunrise.

Reptiles

a. Flushing Transects

The same sampling sites, procedures, etc. used on mammal transects were used for reptiles and amphibians, with two exceptions. Reptiles and amphibians were sampled in June and August only and transects were walked beginning two hours after sunrise and concluding three hours later.

4.3.2.3 Results.

a. Mammals

Mammals consistently found on the tract totaled nineteen species for the years 1975-1977 (Table 42). These include one Lagamorph, fifteen species of Redentia, two Carnivores, and one cervid. Those found sporadically are nine species of Chiroptera, one Lagamorph, three species of Rodentia, five species of Carnivora, and three hoofed mammals, totaling twenty-one additional mammals (Table 43). Mammals reported from previous studies on the tract include three rodents, the Colorado chipmunk (*Eutamias quadrivittatus*) (Perry, 1975), the olive-backed pocket mouse (*Perognathus fasciatus*) (Perry, 1975; Ranck, 1961), and the northern grasshopper mouse (*Onychomys leucogaster*) (Perry, 1975). Mammals found near, but not on, the tract include the white-tailed jackrabbit (Leupus townsendii), the mountain cottontail (*Sylvilagus nuttallii*) (Ranck, 1961), thirteen lined ground squirrel (*Spermophilus tridecemlineatus*), northern pocket gopher (*Thomomys talpoides*) (Perry, 1975; Ranck, 1961), gray fox

Table 42. Mammals observed or captured consistently on the Oil Shale Tracts, 1975-1977.

Order/Family/Species	Order/Family/Species
LAGAMORPHA	RODENTIA - continued
Leporidae	Cricetidae - continued
Desert Cottontail Sylvilagus audubonii	Pinon Mouse Peromyscus truei
RODENTIA	Desert Woodrat Neotoma lepida
Sciuridae	Bushytailed Woodrat Neotoma cinerea
Least Chipmunk Eutamias minimus	Muskrat Ondatra zibethicus
Whitetailed Antelope Squirrel Ammospermophilus leucurus	Erethizontidae
Golden-mantled Ground Squirrel Spermophilus lateralis	Porcupine Erethizon dorsatum
Whitetailed Prairie Dog Cynomys leucurus	CARNIVORA
Heteromyidae	Canidae
Apache Pocket Mouse Perognathus apache	Coyote Canis latrans
Ord Kangaroo Rat Dipodomys ordii	Mustelidae
Castoridae	Badger Taxidea taxus
Beaver Castor canadensis	ARTIODACTYLA
Cricetidae	Cervidae
Western Harvest Mouse Reithrodontomys megalotis	Mule Deer Odocoileus hemionus
Canon Mouse Peromyscus crinitus	
Deer Mouse Peromyscus maniculatus	

Table 43. Mammals observed or captured sporadically on the Oil Shale Tracts, 1975-1977.

Order/Family/Species	Order/Family/Species
CHIROPTERA	CARNIVORA
Vespertilionidae	Procyonidae
Little Brown Bat Myotis lucifugus	Raccoon Procyon lotor
Long-eared Bat Myotis evotis	Mustelidae
Long-legged Bat Myotis volans	Weasel Mustela spp.
Silver-haired Bat Lasionycteris noctivagans	Striped Skunk Mephitis mephitis
Western Pipistrelle Pipistrellus hesperus	Felidae
Big Brown Bat Eptesicus fuscus	Mountain Lion Felis concolor
Hoary Bat Lasiurus cinereus	Bobcat Lynx rufus
Townsend's Big-eared Bat Plecotus townsendii	ARTIODACTYLA
Pallid Bat Antrozous pallidus	Antilocapridae
LAGAMORPHA	Pronghorn Antelope Antilocapra americana
Leporidae	Bovidae
Blacktailed Jackrabbit Lepus californicus	Domestic Cattle Bos taurus
RODENTIA	Domestic Sheep Ovis aries
Sciuridae	
Yellow-bellied Marmot Marmota flaviventris	
Rock Squirrel Spermophilus variegatus	
Cricetidae	
Brush Mouse Peromyscus boylii	

(*Urocyon cinereoargenteus*) (Durrant, 1952; Ranck, 1961), black bear (*Ursus americanus*) (Ranck, 1961), and the spotted skunk (Spilogale putorius) (Osen, 1973). In summary, forty mammals have been observed on tract during 1975-1977. Three other mammals were found on the tract prior to this study, and seven other mammals occurred in the vicinity of the tract.

The distribution of the mammals in space and time finds the desert cottontail in all four habitat types. Their burrow systems are usually located in or near rock outcrops. The only time burrows were used or made away from the outcrops was in 1976 during peak population. The cottontails are active year round.

In the squirrel family, the least chipmunk has been found in the juniper vegetation. A few were observed or captured in the sagebrush-greasewood and in the riparian vegetation in Evacuation Creek and the White River. Their main activity period begins in or just prior to April and ends in October to December depending on the climatic conditions of the year. Whitetailed antelope squirrels occupy the desert shrub areas (sagebrush-greasewood and shadscale). A few live in the juniper and none were found near the White River. They are active year-round, altering their daily activity with the weather conditions. In winter, they are active in midday, while in the summer, they are active in the evening and early morning. Golden-mantled ground squirrels were found in all habitat types, primarily in rocky greasewood draws and in riparian areas of Evacuation Creek and the White River. They also are active year-round. Whitetailed prairie dogs have a large town or series of towns in the shadscale vegetation north of the White River (T10S, R24E, Sec. 1). One or two prairie dogs had set up a burrow system just north of WR-2 in 1975-1976.

None were found here in 1977. In 1976 a few prairie dogs were sighted south of the White River, one near the mouth of Southam Canyon, the other two near Ignatio Stage Stop. They are active in April through October.

Apache pocket mice occur primarily in the desert shrub vegetation. A few live in the juniper and Evacuation Creek and are rarely captured in the riparian vegetation on the White River. Their activity begins in April and ends in November. Ord kangaroo rats, on the other hand, are active year-round. They are limited to the desert shrub vegetation; a few have also been captured in Evacuation Creek.

Beaver are limited to the White River and are active until the river freezes over completely. In August 1977 one young beaver was found dying in the shadscale vegetation about four miles south of the river.

Of the gnawing rodents, all being active year-round, Western harvest mice were captured consistently in the sagebrush-greasewood vegetation of Southam Canyon and Asphalt Wash and along the White River. In 1976 only, they were captured in the shadscale and juniper areas. Canon mice are strictly limited to the juniper areas. Deer mice are found throughout the tract. Pinon mice were captured primarily in the juniper; a few have been captured in the sagebrush-greasewood in Southam Canyon and on the White River bottomlands. Desert woodrats are found throughout the tract, primarily in the juniper. Bushytailed woodrats were captured primarily in the riparian habitats. In 1976 they invaded the juniper habitat and remained there through 1977. In late 1976 through spring 1977, they invaded the sagebrush-greasewood, but have since disappeared. Muskrats occupy the White River; the porcupine is usually found atop a cottonwood tree, although one has been observed in the juniper.

Coyotes are present year-round and, though seldom seen, tracks, scats, and calling have been consistently observed throughout the tract. Badger activity coincides with areas where some soil for burrowing mammals is present, primarily the river banks, arid draws, and canyon floors. Mule deer are present year-round but alter their use of habitat according to the season. In winter, most of the deer leave the river bottomland and the tract, moving south into the pinon-juniper vegetation. In spring, summer and fall, days are spent in the riparian areas and nights in the upland vegetation.

Chiropterans, bats, comprise one group of mammals that were sampled sporadically. There is a considerable diversity in the genera and species of bats that inhabit the tract (Table 44). There is no diversity in where bats can be consistently netted, specifically, the gas pond. As described in the Methods section, mist netting was carried out during May and August 1976 at four sites in addition to Asphalt Wash gas pond. No bats were captured at sites other than Asphalt Wash. The reason for variance in capture success is almost certainly the influence that the gas pond has in concentrating the bats into a small area. Without some concentrating factor, bat sampling is, at best, a "hit and miss" proposition, with a very low probability of success.

Table 45 presents capture data by species and sampling period for 1976 and 1977. The single May 1976 sample provides limited information. The August 1976 and the June and August 1976 data represent the results of comparable mist netting efforts. The Western pipistrelle, hoary bat, silver-haired bat, and pallid bat were captured during three sampling periods. The pipistrelle and hoary bat are by far the most numerous,

Table 44. Species capture summary for the 1976-1977 sampling period. Parenthetical numbers are percent species captures of total captures

Species	1976 May	1976 August	1977 June	1977 August
Western Pipistrelle		12 (35)	21 (47)	21 (55)
Hoary Bat		2 (6)	13 (29)	8 (21)
Silver-haired Bat	1	0	10 (22)	1 (3)
Little Brown Bat	1	8 (21)	0	4 (10)
Long-eared Myotis	1	4 (11)	0	2 (5)
Long-legged Myotis		1 (3)	1 (2)	0
Pallid Bat	2	2 (6)	0	1 (3)
Big Brown Bat	2	0	0	0
Western Big-eared Bat	1	0	0	0
Unidentified Myotines 1/	3	5 (15)	0	1 (3)
Total		34	45	38

1/ Not positively identified; appear to be the Yuma bat (Myotis yumanensis), California bat (Myotis californicus) and the small-footed bat (Myotis subulatus).

Table 45. Weights of bats captured during August 1977.

Species	Sex	Number Weighed	Mean Weight (gm)	Range of Weights (gm)
Western Pipistrelle[1/]	M	13	4 ± .2*	3- 5[2/]
	F	6	5 ± .2	5- 6
Hoary Bat	M	3	23 ± .3	23-24
	F	4	27 ± 1.2	25-29
Silver-haired Bat	M	1	11	-
Little Brown Bat	M	1	4[2/]	-
	F	3	8 ± .4	7- 8
Long-eared Myotis	M	1	3[2/]	-
	F	1	5	-
Pallid Bat	M	1	14	-

[1/] Two specimens of the western pipistrelle are not included in this analysis.

[2/] The range of weights of these specimens indicates that juveniles may be included in the sample.

*Standard error of the mean.

although captures of hoary bats declined in the August samples. The silver-haired bat was captured in numbers in the June 1977 sample, but only once in May 1976 and August 1977, and not at all in August of 1976. The hoary and silver-haired bats are highly mobile species known to undertake substantial seasonal migrations that, in some areas, are as early as mid to late August. This characteristic may result in a low number of August captures. The pallid bat was captured in three of the four samples, but in low numbers. The pallid bat is a ground feeder and takes little food while in flight. Their feeding habits may account for the limited captures of this relatively common bat over a body of water. The big brown bat and the Western big-eared bat were captured only during May 1976. The little brown bat was not captured during June 1977, but was taken during the other periods. The long-eared and the long-legged myotis are not found in any numbers in the Uintah Basin (Durrant, 1952). The three myotines, the two above and the little brown, are not among the highly colonial species of bats. They are not considered solitary, but do not often gather in the very large numbers characteristic of certain other members of the genus. Although the little brown bat is probably the most colonial of the three species, it is generally found in small clusters. This bat will roost in caves, crevices, shrubs, etc., while the long-eared and long-legged myotis do not seem to frequent caves; they roost singly or in small clusters in buildings and trees.

Weights of those species captured in August 1977 are tabulated in Table 46. The smallest are the myotis' and the pipistrelles; the largest, the hoary bat.

Bats of the genus Myotis are often quite difficult to differentiate taxonomically without an in-depth analysis that requires sacrificing the animal. The program during 1976 and 1977 called for the release of all captured animals unharmed. As a result, no bats were retained for laboratory analysis and positive identification of the myotines was not always possible. The little brown and yuma bats are taxonomically similar, as are the California and small-footed myotis. Although the identification of the little brown bat is fairly certain, it could have been confused with the yuma bat. A solution to this problem will be pursued in 1978.

Other mammals occurring sporadically (Table 43) are the black-tailed jackrabbits, first seen in the shadscale in August and October 1976, near the southeast corner of the tract. In 1977, one was observed in the juniper area on the WJ-4 transect.

A yellow-bellied marmot was first observed in August 1975 and April 1976 in Asphalt Wash, a sagebrush-greasewood area transect. Rock squirrels were observed in Wagon Hound Canyon and a side canyon leading into Hell's Hole Canyon in October 1976 only. Brush mice were captured in the shadscale in August 1975 and 1976.

Raccoon tracks were found along the White River near the mouth of Hell's Hole Canyon. Weasels have been observed only in Southam Canyon. One dead striped skunk was found in the river bottomlands and tracks have been found near the river. A single sighting of a mountain lion occurred just north of the White River in June 1975. Bobcats have been heard in the rock cliffs along the river, and one was captured by a private trapper in a side canyon of Asphalt Wash.

Pronghorn antelope have consistently been seen north of the tract near Bonanza, Utah. In 1977, a quite dry year, small herds entered the

tract boundaries near the White River. Domestic sheep enter the tract in December of each year and leave by the end of April. One resident herd of about 1800 ranges throughout Southam Canyon during this time. Thousands of sheep are driven through Tract Ub in December, heading toward their winter range, and again in April when they are rounded up for shearing and transportation to their summer range. Cattle forage along the White River, Evacuation Creek and the greasewood draws leading away from the river beginning in July. They are rounded up and transported out of the area in late October and early November.

Mammalian abundance during the past three years (1975-1977), as determined from flushing transects, began with an average of 12 mammals observed per sampling period in 1975, increased in 1976 to 41 mammals observed per sampling period, and decreased slightly in 1977 to 34 mammals observed per sampling period [n = 48 (four sampling periods/three years/four vegetation types), α = .05, F = 6.7457] (Figure 68).

Mean abundance in habitat type shows that the riparian and sagebrush-greasewood associations are practically equal and the same for the shadscale and juniper at a lower level. Statistically, mammalian abundance did not differ between vegetation types. However, increase in abundance through each year peaked in August (n = 48, α = .05, F = 5.2313) (Table 46 and Figure 68).

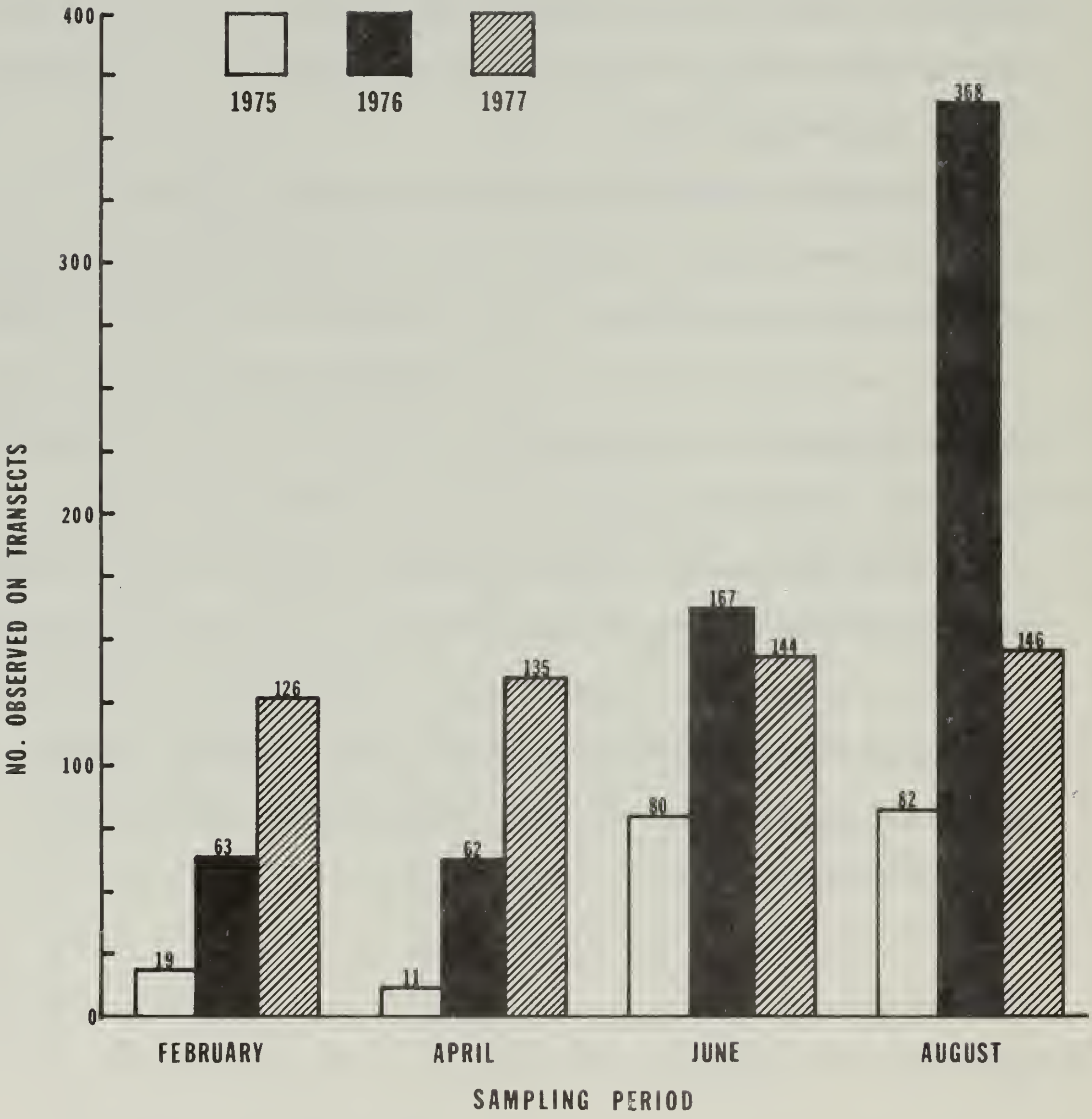


Figure 68. Mammalian abundance for three consecutive years on the Utah Oil Shale Tracts. Abundance was determined from flushing transects.

Table 46. Mammalian abundance from flushing transects, 1975-1977, presented in numbers/habitat type/sampling period.

Habitat Type	Sampling Period Feb.	Apr.	June	Aug.	Mean
Riparian	15	29	33	66	36
Sagebrush-greasewood	24	12	52	53	35
Shadscale	20	12	26	36	24
Juniper	10	15	20	44	22
Mean	17 [a]	17 [a]	33	50 [a]	

[a]Significantly different at $p \geq .95$.

The wide fluctuations in abundance are due primarily to the cottontails. Chipmunks and antelope squirrels accounted for a small portion of the abundance in 1975 and 1976 in the desert shrub and juniper areas. In 1977, in the second year of drought, these mammals were seldom seen. In the riparian vegetation, beaver, porcupine, mule deer, and bats in the summer made up a fair population of mammalian abundance. Overall, the cottontail proved consistently the most abundant.

Whitetailed prairie dog abundance peaked in late 1976. In 1975, the prairie dogs confined most of their activity to their town north of the river. As the other mammals increased, so did the prairie dogs,

indicated by the number of sightings long distances from the town. In 1977 little activity could be observed. Beaver and procupine followed the same pattern, as indicated by transect observations. Muskrat populations have been, and continue to be, quite low. Coyote populations as indicated by tracks, scats, howling, and sightings, have consistently been low. The pattern has been the same for badger. Mule deer populations appeared to be on the increase in 1976. Observations in 1977 suggest that population growth leveled off or decreased.

Rodent densities throughout the tract, as determined by large trap grids, doubled from 1975 to 1976 (19 rodents/ha to 40 rodents/ha) and decreased by a factor of 8 in 1977 (5 rodents/ha) (Table 47).

The sagebrush-greasewood habitat has through the years had the highest density of rodents, averaging 26/ha. Whitetailed antelope squirrels almost doubled in populations from 1975 to 1976. In 1977 none were captured and observations were rare. Apache pocket mice maintained a steady population for 1975 and 1976 and decreased by half in 1977. Kangaroo rats, however, have remained at a steady population for all three years. Western harvest mice numbers peaked in 1976. Deer mice showed the greatest fluctuations in density, doubling to 21/ha in 1976 and decreasing to 1/ha in 1977. The desert woodrat populations have remained low through the years (Table 48).

Table 47. Rodent densities as determined from trap grids in all habitat types (sagebrush-greasewood, juniper, shadscale, and riparian). Area trapped in 1975 and 1976 equalled 9.4 ha; in 1977 area trapped equalled 10.88 ha.

Species	1975		1976		1977	
	Individuals Captured	Number/ Hectare	Individuals Captured	Number/ Hectare	Individuals Captured	Number/ Hectare
Golden-mantled Squirrel	1	0.1	1	0.1	0	0
White-tailed Antelope Squirrel	28	3.0	36	3.8	0	0
Least Chipmunk	3	0.3	11	1.2	0	0
Apache Pocket Mouse	33	3.5	28	3.0	15	1.4
Ord Kangaroo Rat	23	2.4	23	2.4	19	1.7
Western Harvest Mouse	0	0	12	1.3	0	0
Canon Mouse	4	0.4	8	0.8	1	0.1
Deer Mouse	65	6.9	196	20.8	13	1.2
Pinon Mouse	0	0	15	1.6	0	0
Brush Mouse	1	0.1	2	0.2	0	0
Desert Woodrat	22	2.3	33	3.5	7	0.6
Bushytail Woodrat	2	0.2	12	1.3	1	0.1
Total	182	19.2	377	40.1	56	5.1

Table 48. Three years of rodent densities for the sagebrush-greasewood vegetation type on the Utah Oil Shale Tracts.

Species	1975 Ind. Captured	1975 Density No./ha	1976 Ind. Captured	1976 Density No./ha	1977 Ind. Captured	1977 Density No./ha
Whitetailed Antelope Squirrel	10	4	17	6	0	0
Least Chipmunk	1	< 1	1	< 1	0	0
Apache Pocket Mouse	19	7	17	6	7	3
Ord Kangaroo Rat	16	6	14	5	14	5
Western Harvest Mouse	0	0	5	2	0	0
Deer Mouse	25	9	56	21	3	1
Pinon Mouse	0	0	2	1	0	0
Desert Woodrat	2	1	5	2	2	1
Total	73	27	117	43	26	10

Rodent movement within the trap grid showed that antelope squirrels covered the greatest distances, followed by the deer mice and the desert woodrats. The heteromyids (pocket mice and kangaroo rats) moved the least (Table 49). The increase in deer mouse density in 1976 resulted in a substantial decrease in movement ($n = 125$, $\alpha = .05$, $F = 4.0027$).

The shadscale vegetation closely followed the sagebrush-greasewood vegetation in overall rodent density (averaging 24 rodents/ha) and in species composition through three years. The main difference in the

Table 49. Movement by rodents captured two or more times in the sagebrush-greasewood vegetation. Distance traveled was determined by a straight line between trap stations in the large trap grid conducted in August.

Species	1975			1976			1977		
	Single Capture	Multiple Capture	Movement, Meters	Single Capture	Multiple Capture	Movement, Meters	Single Capture	Multiple Capture	Movement, Meters
Whitetailed Antelope Squirrel	6	4	53 ± 15	7	10	50 ± 11	0	0	0
Apache Pocket Mouse	8	11	10 ± 4	6	11	16 ± 4	4	3	29 ± 18
Ord Kangaroo Rat	3	13	13 ± 2	3	11	20 ± 3	0	14	25 ± 4
Deer Mouse	10	15	31 ± 5	18	38	18 ± 2	3	0	0
Desert Woodrat	0	2	39 ± 11	0	5	13 ± 5	1	1	78 ± 30

two vegetation types are that in the shadscale the heteromyids are at lower, but steadier densities, and deer mice are more eruptive, quadrupling their density in 1976. Data presented in Table 51 shows no antelope squirrel captures in the shadscale in 1977; deer mice exhibit a similar pattern. Western harvest mice invaded the area in 1976, but were not captured in 1977. Desert woodrat populations peaked in 1976. Overall, the shadscale vegetation demonstrated the most variable densities of the four habitats studied (Table 50).

Table 50. Three years of rodent densities for the shadscale vegetation type on the Utah Oil Shale Tracts.

Species	1975		1976		1977	
	Ind. Captured	Density No./ha	Ind. Captured	Density No./ha	Ind. Captured	Density No./ha
Golden-mantled Squirrel	1	< 1	0	0	0	0
Whitetailed Antelope Squirrel	16	6	18	7	0	0
Apache Pocket Mouse	6	2	8	3	7	3
Ord Kangaroo Rat	7	3	9	3	5	2
Western Harvest Mouse	0	0	3	1	0	0
Deer Mouse	19	7	83	30	0	0
Brush Mouse	1	< 1	1	< 1	0	0
Desert Woodrat	1	< 1	7	3	0	0
Total	51	19	129	47	12	4

Rodent movement in the shadscale grid was highest by the antelope squirrels. Heteromyid movement averaged higher in the shadscale than the sagebrush-greasewood. With the increase in deer mouse density in 1976, their movement also decreased significantly ($n = 131, \alpha = .05, F = 1112$) Table 51).

The juniper vegetation through the years has supported on the average only 18 rodents/ha; however, the greatest diversity of rodents were in the juniper vegetation areas. Deer mouse density is relatively low and is surpassed by desert woodrats. Also, two other species of Peromyscus and the busy-tailed woodrat also live in the juniper. Pinon mice invaded the juniper in 1976 at a relatively high density. The change that led to this invasion and reproduction was absent in 1975 and 1977 (Table 52).

Rodent movement in the juniper was relatively high for all rodents with the exception of the desert woodrat, whose distance traveled stayed stable and relatively low (Table 53). Differences in deer mice movement could not be separated statistically.

The riparian vegetation, the area of highest plant density on the tract, supports the lowest density of rodents, 12/ha, and the least diversity. The only rodent consistently caught in the White River bottomlands was the deer mouse. They followed the same pattern in 1975 and 1976 as the mice in other habitats and were as eruptive as deer mice in the shadscale. In 1977 their density declined to below the 1975 level (Table 54).

Table 51. Movement by rodents captured two or more times in the shadscale vegetation. Distance traveled was determined by a straight line between trap stations in the large trap grid conducted in August.

Species	1975			1976			1977		
	Single Capture	Multiple Capture	Distance, Meters	Single Capture	Multiple Capture	Distance, Meters	Single Capture	Multiple Capture	Distance, Meters
Whitetailed Antelope Squirrel	11	5	43 ± 10	10	8	50 ± 9	0	0	0
Apache Pocket Mouse	4	2	27 ± 8	1	7	22 ± 6	3	4	30 ± 16
Ord Kangaroo Rat	3	4	24 ± 4	1	8	22 ± 6	0	5	8 ± 2
Deer Mouse	4	15	41 ± 5	31	52	23 ± 2	0	0	0
Desert Woodrat	0	1	70 ± 25	1	6	22 ± 5	0	0	0

Table 52. Three years of rodent densities for the juniper vegetation type on the Utah Oil Shale Tracts.

Species	1975 Ind. Captured	1975 Density No./ha	1976 Ind. Captured	1976 Density No./ha	1977 Ind. Captured	1977 Density No./ha
Golden-mantled Squirrel	0	0	1	<1	0	0
Whitetailed Antelope Squirrel	2	1	1	<1	0	0
Least Chipmunk	2	1	9	3	0	0
Apache Pocket Mouse	7	3	3	1	1	<1
Western Harvest Mouse	0	0	1	<1	0	0
Canon Mouse	4	2	8	3	1	<1
Deer Mouse	13	5	24	9	0	0
Pinon Mouse	0	0	13	5	0	0
Desert Woodrat	18	7	21	8	5	2
Bushytail Woodrat	0	0	8	3	1	<1
Total	46	17	89	33	8	3

Table 53. Movement by rodents captured two or more times in the juniper vegetation. Distance traveled was determined by a straight line between trap stations in the large trap grid conducted in August.

Species	1975			1976			1977		
	Single Capture	Multiple Capture	Movement, Meters	Single Capture	Multiple Capture	Movement, Meters	Single Capture	Multiple Capture	Movement, Meters
Least Chipmunk	2	0	0	3	6	69 ± 14	0	0	0
Apache Pocket Mouse	1	6	50 ± 13	0	3	36 ± 12	0	1	21 ± 6
Canon Mouse	2	2	94 ± 21	3	5	58 ± 14	1	0	0
Deer Mouse	3	10	41 ± 6	8	16	36 ± 5	0	0	0
Pinon Mouse	0	0	0	2	11	49 ± 9	0	0	0
Desert Woodrat	5	13	22 ± 3	1	20	22 ± 2	0	5	25 ± 6
Bushytailed Woodrat	0	0	0	4	4	23 ± 6	0	1	75

Table 54. Three years of rodent densities for the riparian vegetation type on the Utah Oil Shale Tracts.

Species	1975 Ind. Captured	1975 Density No./ha	1976 Ind. Captured	1976 Density No./ha	1977 Ind. Captured	1977 Density No./ha
Least Chipmunk	0	0	1	1	0	0
Apache Pocket Mouse	1	1	0	0	0	0
Western Harvest Mouse	0	0	3	2	0	0
Deer Mouse	8	6	33	27	10	4
Brush Mouse	0	0	1	1	0	0
Desert Woodrat	1	1	0	0	0	0
Bushytail Woodrat	2	2	4	3	0	0
Total	12	10	42	34	10	4

The differences in the three years in the riparian vegetation are reflected in the movement patterns. In 1975, movement averaged 30 ± 6 m and in 1976, 27 ± 3 m. In 1977, movement doubled to 62 ± 15 m (n = 89, α = .05, F - 7.5553).

Comparing deer mouse movement in all habitat types from three years, distance traveled was highest in the juniper (38 m) and the riparian areas (33 m). Distance moved in the shadscale (27 m) was significantly lower than movement in the juniper, but the same as movement in the riparian and the sagebrush-greasewood (22 m). Movement in the latter vegetation was significantly lower than movement in both the juniper and riparian vegetation (n = 400, α = .05, F = 5.8960).

Rodent weights and sex ratios were measured in the small trap grids conducted from February to August 1977, plus the large grid in August. The largest rodent was a 305 g adult male busytailed woodrat, and the smallest was a 6 g juventile male western harvest house (Table 55). Sex ratios distinctly favored the males in least chipmunks, kangaroo rats and western harvest mice (Table 55). Sex ratios were 1:1 in the woodrats, but slightly favored males in pocket mice and deer mice.

The small trap grids conducted in February, April, June and August 1977 showed that deer mouse activity in winter was high when compared to late summer. The only area that had a relatively high deer mouse population through 1977 in the riparian vegetation.

Birds

There have been 134 species of birds present on the tract from 1975 through 1977. Approximately 57 percent of the species total (76 species) have been consistent in their presence for three years.

The first group is the permanent residents, consisting of 13 different birds (Table 56). Four are raptors. Golden eagles forage in all habitat types and next in the sandstone cliffs off tract. Eagle activity is highest in the winter when prey activity is least. In the first winter on the tract, seven eagles, all appearing to be subadult, were seen foraging in a flock. Marsh hawks are few and confine their activity to the shadscale vegetation in Tract Ub. However, one female was seen in Southam Canyon in April 1977. No nests have been found on tract. Prairie falcons have nested consistently on tract in the sandstone cliffs between Southam Canyon and Evacuation Creek. The fourth raptor, the great

Table 55. Body weights in grams and age-sex ratios for rodents captured in all vegetation types on the Utah Oil Shale Tracts.

Species	n	Adult Female	n	Adult Male	n	Juvenile Female	n	Juvenile Male
Least Chipmunk	1	50	7	52 ± .2*				
Apache Pocket Mouse	21	11 ± .3	26	12 ± .2				
Ord Kangaroo Rat	13	58 ± 1 1/	36	64 ± .8	1	45		
Western Harvest Mouse	1	10	7	12 ± .6			1	6
Canon Mouse	2	19 ± 1	1	20			1	15
Deer Mouse	49	21 ± .4	65	21 ± .3	6	14 ± .6	3	15 ± 1
Pinon Mouse	1	18 2/						
Desert Woodrat	11	125 ± 6	11	142 ± 9	5	69 ± 8		
Bushytailed Woodrat	4	229 ± 13	4	281 ± 14	1	135	1	160

*Standard error of the mean.

1/ Three females captured in February and April were 64.7 ± 1.8 g in weight. The ten females captured in August may be subadult females, thus the low weight.

2/ This female is not indicative of the size of a pinon mouse. She died in the trap the night after this capture.

Table 56. Avian permanent residents present for three consecutive years on the Utah Oil Shale Tracts.

Order/Family/Species	Order/Family/Species
FALCONIFORMES	PASSERIFORMES
Accipitridae	Alaudidae
Golden Eagle Aquila chrysaetos	Horned Lark Eremophilus alpestris
Marsh Hawk Circus cyaneus	Corvidae
Falconidae	Black-billed Magpie Pica pica
Prairie Falcon Falco mexicanus	Pinon Jay Gymnorhinus cyanocephalus
STRIGIFORMES	Paridae
Strigidae	Black-capped Chickadee Parus atricapillus
Great Horned Owl Bubo virginianus	Plain Titmouse Parus inornatus
PICIFORMES	Laniidae
Picidae	Loggerhead Shrike Lanius ludovicianus
Common Flicker Colaptes auratus	
Hairy Woodpecker Dendrocopus villosus	
Downy Woodpecker Dendrocopus pubescens	

horned owl, nests in the sandstone cliffs and in the cottonwoods along the White River. Some may nest in the juniper, but this has not been confirmed.

Great horned owls showed the only definitive increase in abundance among all the raptors on the tract. Where none were seen on transects in 1975, and one in 1976, 22 were seen in 1977. To attest to this increase, 4 fledglings and an adult were flushed from a cottonwood tree in June 1977.

Three permanent residents are woodpeckers, the common flicker, the hair woodpecker, and the downy woodpecker. The hairy and downy woodpeckers live strictly among the cottonwoods and willows in the river bottom. The common flicker is most commonly observed in this area, but also resides in the junipers, and is occasionally seen foraging in the sagebrush-greasewood. Both the woodpeckers' populations appear stable, although the hairy woodpecker is seen inconsistently. Flickers, however, reached a peak in April and June 1977 -- 68 observed. Four were observed for the same period in 1975, and 14 in 1976.

The six remaining permanent residents are passerines. Horned larks are most evident in winter when flocks can be seen foraging in all habitat types. However, their preferred habitat is the shadscale, both winter and summer. The difference between seasons is number. As many as 132 horned larks have been seen in the shadscale in winter (February 1976) and as few as one horned lark in summer (June, August 1976).

Two corvids, black-billed magpies and pinon jays, are also year-round residents. The magpies are distributed throughout the tract, although they nest primarily in the juniper and cottonwoods and some in the sandstone cliffs in these areas. Magpie abundance has been increasing. In the February, April, June and August sampling periods in 1975, 43 were observed

on transect. This increased to 63 for the same period in 1976 and to 99 in 1977. Pinon jays confine themselves to the sagebrush-greasewood and juniper areas except in August when they also forage in the shadscale and riparian areas. Their abundance, based on the same four sampling periods, went from 304 to 393 in 1975 and 1976, respectively, to 78 in 1977.

The two smallest permanent residents are the black-capped chickadees found only in the riparian vegetation, and the plain titmouse, found primarily in the juniper vegetation, although the titmouse forages in the adjacent sagebrush-greasewood. In 1975 the chickadee abundance was nine from transects. In 1976 the number increased to 24 and remained stable in 1977 at 22. Titmouse abundance in the juniper was 10 in 1975, increasing to 33 in 1976, and going back to 10 in 1977.

The least permanent resident is the loggerhead shrike, also known as the butcher bird. Shrikes who prey on mice, birds, and probably lizards, will hand what they do not immediately consume from a barb on a greasewood bush. Shrikes are predominantly a dryland vegetation species, preferring the shadscale and sagebrush-greasewood types. Their occurrence in the riparian vegetation has only been recorded in winter. Shrike abundance has coincided with rodent densities, 28 observed on transect in 1975, to 53 in 1976, and down to 17 in 1977.

The common raven, a permanent resident south of the tract toward the Book Cliffs, is a rather common sight in the winter and is sporadically seen in spring, summer and fall. A few scrub jays have nested on the tract in the juniper and riparian areas and appear to be permanent residents, although sightings are too few and too sporadic to be certain.

One other species who is a questionable permanent resident is the canon wren. They have nested and wintered in the White River canyon and

in rocky greasewood or juniper draws in the upland from 1976 through 1977. Their abundance, from transects, increased slightly in 1977.

Winter residents comprise the second class of birds. Four species have been consistently observed on the tract from 1975 through 1977 (Table 57).

Table 57. Avian winter residents present for three consecutive years on the Utah Oil Shale Tracts.

Order/Family/Species	Order/Family/Species
FALCONIFORMES	PASSERIFORMES
Accipitridae	Fringillidae
Goshawk Accipiter gentilis	Black Rosy Finch Leucosticte atrata
Bald Eagle Haliaeetus	Dark-eyed Junco (Oregon and Slate colored Juncoes) Junco hyemalis

A few goshawks winter in the riparian vegetation and also utilize the juniper, primarily in January and February, and as early as October. A few bald eagles also winter along the White River and are occasionally seen in the shadscale vegetation. They are present from December through February. Large flocks of black rosy finches are a common winter sight. Rosy finch abundance peaked in February 1976, as did the abundance of the other winter resident, the dark-eyed juncoes. The finches are on the tract from December through February, with a few stragglers occurring

in April. Juncoes usually arrive in force in October and remain through April, with an occasional straggler present in June.

Two other winter residents, present only in 1975 and 1976, are the bushtit and the tree sparrow. Both are particular to the riparian vegetation, although flocks of bushtits have also occurred in the juniper vegetation.

A third classification of the avians inhabiting the tract are the transients, including both spring and fall migrants. This group includes 13 species (Table 58) who have been consistently present. Birds that are consistent spring-fall migrants (April and October) are sandhill cranes, belted kingfisher, Townsend's solitaire (an altitudinal migrant), ruby-crowned kinglets, yellow-rumped warblers, and vesper sparrows. Common mergansers occurred only in February, once in April. Poor-wills are seen in the juniper and blue grosbeaks in the riparian vegetation in August only. Cedar waxwings occur in the riparian vegetation in June only. Green-winged teal and song sparrows are seen in the spring along the White River. Only the cranes, the solitaires, waxwings, and yellow-rumped warblers, plus an inconsistently-occurring transient, the yellow-bellied sapsucker (Sphyrapicus varius), are present in number.

A few birds who had previously been classified as transients (Anon., 1977), nested on the tract in 1977 -- barn swallow, house wren, and Bewick's wren.

The fourth and largest classification of birds is the summer residents, accountimg for 46 species (Table 59). The only waterfowl are Canada geese and mallards. Goose activity is centered on the White River and is high in April. Few are seen in June when the parents and goslings

Table 58. Avian transients present for three consecutive years on the Utah Oil Shale Tracts.

Order/Family/Species	Order/Family/Species
ANSERIFORMES	PASSERIFORMES (continued)
Anatidae	Sylviidae
Green-winged Teal* Anas crecca	Ruby-crowned Kinglet Regulus calendula
Common Merganser Mergus merganser	Bombycillidae
GRUIFORMES	Cedar Waxwing Bombycilla cedrorum
Gruidae	Parulidae
Sandhill Crane Grus canadensis	Yellow-rumped Warbler (Audubon's and Myrtle Warbler) Dendroica coronata
CAPRIMULGIFORMES	Icteridae
Caprimulgidae	Scott's Oriole* Icterus parisorum
Poor-will* Phalaenoptilus nuttallii	Fringillidae
CORACIIFORMES	Blue Grosbeak Guiraca caerulea
Alcedinidae	Vesper Sparrow Pooecetes gramineus
Belted Kingfisher Megaceryle alcyon	Song Sparrow* Melospiza melodia
PASSERIFORMES	
Turdidae	
Townsend's Solitaire Myadestes townsendi	

*Likely summer residents, though unconfirmed.

Table 59. Avian summer residents present on the Utah Oil Shale Tracts from 1975 through 1977.

Order/Family/Species	Order/Family/Species
ANSERIFORMES	APODIFORMES
Anatidae	Apodidae
Canada Goose Branta canadensis	White-throated Swift Aeronautes saxatalis
Mallard Anas platyrhynchos	Trochilidae
FALCONIFORMES	Broad-tailed Hummingbird Selasphorus platycercus
Cathartidae	PASSERIFORMES
Turkey Vulture Cathartes aura	Tyrannidae
Accipitridae	Ash-throated Flycatcher Myiarchus cinerascens
Red-tailed Hawk Buteo jamaicensis	Say's Phoebe Sayornis saya
Falconidae	Willow Flycatcher Empidonax traillii
Kestrel (Sparrow Hawk) Falco sparverius	Gray Flycatcher Empidonax wrightii
CHARADRIIFORMES	Western Wood Peewee Contopus sordidulus
Charadriidae	Hirundinidae
Killdeer Charadrius vociferus	Violet-green Swallow Tachycineta thalassina
Scolopacidae	Rough-winged Swallow Stelgidopteryx ruficollis
Spotted Sandpiper Actitus macularia	Cliff Swallow Petrochelidon pyrrhonota
COLUMBIFORMES	Troglodytidae
Columbidae	Rock Wren Salpinctes obsoletus
Mourning Dove Zenaida macroura	Mimidae
CAPRIMULGIFORMES	Sage Thrasher Oreoscoptes montanus
Caprimulgidae	
Common Nighthawk Chordeiles minor	

Table 59. Continued

Order/Family/Species	Order/Family/Species
PASSERIFORMES (continued)	PASSERIFORMES (continued)
Turdidae	Icteridae (continued)
American Robin Turdus migratorius	Brewer's Blackbird Euphagus cyanocephalus
Mountain Bluebird Sialia currucoides	Brown-headed Cowbird Molothrus ater
Sylviidae	Thraupidae
Blue-grey Gnatcatcher Polioptila caerulea	Western Tanager Piranga ludoviciana
Sturnidae	Fringillidae
Starling Sturnus vulgaris	Lazuli Bunting Passerina amoena
Vireonidae	House Finch Carpodacus mexicanus
Warbling Vireo Vireo gilvus	American Goldfinch Spinus tristis
Parulidae	Rufous-sided Towhee Pipilo erythrophthalmus
Yellow Warbler Dendroica petechia	Lark Sparrow Chondestes grammacus
Black-throated Gray Warbler Dendroica nigrescens	Black-throated Sparrow Amphispiza bilineata
Common Yellowthroat Geothlypis trichas	Sage Sparrow Amphispiza belli
Yellow-breasted Chat Icteria virens	Chipping Sparrow Spizella passerina
Icteridae	Brewer's Sparrow Spizella breweri
Western Meadowlark Sturnella neglecta	White-crowned Sparrow Zonotrichia leucophrys
Red-winged Blackbird Agelaius phoeniceus	
Northern Oriole (Bullock's and Baltimore Oriole) Icterus galbula	

decrease their activity, and by August the geese are gone. This occurred in 1975 and 1976, but not in 1977. During the latter year, the geese stayed on the river through August. Very few mallards are present on the tract.

Seventeen species were at their highest abundance in 1975 and have consistently declined through 1977 (Table 60). Eight of the summer residents have maintained a stable abundance, whereas eight others have increased in abundance (Table 61). Habitat and temporal distribution for the other 10 summer residents are in Table 62.

The remainder of the avifauna, 58 species (some who have already been mentioned), that have occurred sporadically are year-round residents (4 species), winter resident (3 species), transients (34 species), and summer residents (17 species) (Table 63).

Two species that have been observed are threatened and endangered. Peregrine falcons may have nested on the tract in 1975. This is suggested by sightings in April and then sighting a pair in August. The pair in August were feeding and calling near site WR-1. They flew east up river, were joined by two unidentified falcons, and then all four flew into a side canyon south of the river. The other species was a whooping crane in the company of some 300 sandhill cranes, all flying south in October 1976.

A red-eyed vireo, an uncommon transient (Behle and Perry, 1975) occurred in the cottonwoods in June 1975. A rose-breasted grosbeak, an occasional (ibid., p. 40) occurred in June 1976 in the juniper. A hypothetical species for the state of Utah (ibid., p. 33), the black-tailed gnatcatcher, nested in the greasewood in Evacuation Creek and the White River. They arrived in April 1975 and were present through August 1975. There was no mistake in identification since both species of gnatcather

Table 60. Declining Abundance of seventeen avian summer residents and their habitat preference (S-G - sagebrush-greasewood; J - juniper; S - shadscale; R - riparian) on the Utah Oil Shale Tracts.

Species	Combined Abundance From Flushing Transects for June-August Sampling Periods 1975	1976	1977	Habitat Preference in Descending Order
Turkey Vulture	9	X	X	R, S
Mourning Dove	239	56	33	All
Say's Phoebe	23	20	11	All
Violet-green Swallow	12	4	X	S-G, R
Rough-winged Swallow	21	13	4	R, S
Cliff Swallow	390	48	27	R
Rock Wren	111	63	39	All
Sage Thrasher	15	11	3	S, S-G
Mountain Bluebird	27	23	7	J, S-G, R
Starling	10	8	3	R
Western Meadowlark	74	67	15	S, S-G, R
Lazuli Bunting	24	6	2	R
Rufous-sided Towhee	65	54	21	R, S-G
Lark Sparrow	66	57	26	All
Sage Sparrow	87	45	7	S, S-G
Chipping Sparrow	85	33	14	J, S-G, R
Brewer's Sparrow	213	33	1	S-G, S, R

X - Present, but none observed on transect.

Table 61. Stable abundance for eight avian summer residents and increasing abundance for eight avian summer residents and their habitat preferences (S-G - sagebrush-greasewood; J - juniper; S - shadscale; R - riparian) on the Utah Oil Shale Tracts.

Species	Combined Abundance From Flushing Transects for June-August Sampling Periods 1975	1976	1977	Habitat Preference in Descending Order
Stable				
Kestrel	7	8	6	All
Spotted Sandpiper	14	19	13	R
Gray Flycatcher	20	15	15	J, S-G
Black-throated Gray Warbler	22	18	16	J, S-G
Yellow-breasted Chat	16	15	14	R
Brown-headed Cowbird	46	51	54	R
Western Tanager	11	7	9	R
Black-throated Sparrow	70	64	63	S-G, S, J
Increasing				
White-throated Swift	2	3	33	R, S, J
Ash-throated Flycatcher	4	7	27	R, J
American Robin	9	14	32	R
Blue-gray Gnatcatcher	17	37	56	R, J
Yellow Warbler	67	51	102	R
Northern Oriole	6	16	24	R
House Finch	58	101	204	R, J
American Goldfinch	X	11	9	R

Table 62. Habitat preference and temporal distribution of 10 summer residents on the Utah Oil Shale Tracts. (Habitat SG - sagebrush-greasewood; J - juniper; S - shadscale; R - riparian)

Species	Habitat Preference				Temporal Distribution by Sampling Period
	S-G	J	S	R	
Red-tailed Hawk	X	X	X	X	April-October, over-wintered in 1977
Killdeer	-	-	X	X	April-August
Common Nighthawk	X	X	X	X	June-August
Broad-tailed Hummingbird	X	X	X	X	June-August
Willow Flycatcher	-	-	-	X	June-August
Western Wood Peewee	-	X	-	X	June-August
Warbling Vireo	-	-	-	X	June-August
Common Yellowthroat	-	-	-	X	June
Red-wing Blackbird	X	-	-	X	April-June
Brewer's Blackbird	X	X	X	X	April-June
White-crowned Sparrow	X	-	-	X	April-June, October

X Presence

- Absence

Table 63. Avian species of varied status present sporadically during 1975-1977 on the Utah Oil Shale Tracts. (Habitat SG - sagebrush-greasewood; J - juniper; S - shadscale; R - riparian.)

Species	Habitat Distribution S-G	J	S	R	Temporal Distribution by Sampling Period
YEAR-ROUND RESIDENTS					
Cooper's Hawk Accipiter cooperii	-	X	-	X	
Scrub Jay Aphelocoma coerulescens	-	X	-	X	
Common Raven Corvus corax	X	X	X	X	
Canon Wren Catherpes mexicanus	X	X	-	X	
WINTER RESIDENTS					
Rough-legged Hawk Buteo lagopus	X	X	X	-	February, 1976
Bushtit Psaltriparus minimus	X	X	-	X	Dec., 1974; Oct., Dec., 1975; Feb., Apr., June, 1976
Tree Sparrow Spizella arborea	X	-	-	X	Feb., Oct., 1975, Feb., 1976
TRANSIENTS					
Gadwall* Anas strepera	-	-	-	X	Apr., June, 1975, 1976
Pintail Anas acuta	-	-	-	X	June, 1975
Blue-winged Teal Anas discors	-	-	-	X	Oct., 1976; Apr., 1977
Cinnamon Teal* Anas cyanoptera	-	-	-	X	Apr., 1976, June, 1977
American Wigeon Anas americana	-	-	-	X	June, 1975
Northern Shoveler Anas clypeata	-	-	-	X	June, 1975; Apr., June, 1976

Table 63. Continued

Species	Habitat Distribution S-G	J	S	R	Temporal Distribution by Sampling Period
TRANSIENTS - Continued					
Swainson's Hawk *Buteo swainsoni*	-	-	X	-	June, 1976
Peregrine Falcon* *Falco peregrinus*	-	-	X	X	Apr., Aug., 1975
Ring-necked Pheasant *Phasianus colchicus*	X	-	-	X	June, 1976
Chukar *Alectoris graeca*	-	-	X	-	Aug., 1977
Whooping Crane *Grus americana*	Flying over tracts				Oct., 1976
Common Snipe *Capella gallinago*	-	-	-	X	Apr., 1975
Greater Yellowlegs *Totanus melanoleucus*	-	-	-	X	Apr., 1976, 1977
Long-eared Owl *Asio otus*	-	-	-	X	Feb., Dec., 1975, Feb., 1976
Short-eared Owl *Asio flammeus*	-	-	-	X	Apr., 1975
Black-chinned Hummingbird* *Archilochus alexandri*	-	-	-	X	June, 1977
Yellow-bellied Sapsucker *Sphyrapicus varius*	-	-	-	X	Apr., June, 1975; Oct., 1976
Eastern Phoebe *Sayornis phoebe*	-	-	-	X	Oct., 1976
Clark's Nutcracker *Nucifraga columbiana*	-	X	-	-	Oct., 1975
Mountain Chickadee *Parus gambeli*	-	X	-	X	Oct., 1976
White-breasted Nuthatch *Sitta carolinensis*	-	-	-	X	Aug., 1976, 1977
Red-breasted Nuthatch *Sitta canadensis*	-	X	-	-	Aug., 1976

Table 63. Continued

Species	Habitat Distribution S-G	J	S	R	Temporal Distribution by Sampling Period
TRANSIENTS - Continued					
Brown Creeper Certhia familiaris	-	-	-	X	Oct., 1976
Hermit Thrush Catharus guttatus	-	-	-	X	June, Oct., 1976
Swainson's Thrush Catharus ustulatus	-	-	-	X	Oct., 1975; Aug., 1976
Western Bluebird Sialia mexicana	-	X	-	X	Apr., 1975, 1977
Water Pipit Anthus spinoletta	-	-	X	X	Apr., 1975, 1976; Oct., 1976
Red-eyed Vireo Vireo olivaceous	-	-	-	X	June, 1975
Rose-breasted Grosbeak Pheucticus ludovicianus	-	X	-	-	June, 1976
Pine Siskin Spinus pinus	-	X	-	X	Oct., 1975; Dec., 1976
Green-tailed Towhee Chlorura chlorura	X	-	-	X	Apr., 1975, Aug., 1976
Savannah Sparrow Passerculus sandwichensis	-	-	X	-	Apr., 1976
Gray-headed Junco Junco caniceps	X	X	-	X	June, 1976; Apr., 1977
SUMMER RESIDENTS					
Great Blue Heron Ardea herodias	-	-	-	X	Apr., June, Aug., 1976, 1977
Sharp-shinned Hawk** Accipiter striatus	-	-	X	X	Feb., Apr., 1976, 1977
Yellow-billed Cuckoo Coccyzus americanus	-	-	-	X	June, 1977
Eastern Kingbird Tyrannus tyrannus	-	-	-	X	June, Aug., 1975
Western Kingbird Tyrannus verticalis	X	X	X	X	Apr., June, Aug., 1975, 1976

Table 63. Continued

Species	Habitat Distribution S-G	J	S	R	Temporal Distribution by Sampling Period
SUMMER RESIDENTS - Continued					
Western Flycatcher** Empidonax difficilis	-	-	-	X	June, 1977
Barn Swallow Hirundo rustica	-	-	-	X	June, 1977 (Transient: Oct., 1975, 1976)
House Wren Troglodytes aedon	X	-	-	X	Apr., Aug., 1976; June, 1977
Bewick's Wren Thyromanes bewickii	X	X	-	X	Apr., 1976; Apr., Aug., 1977
Mockingbird Mimus polyglottis	X	-	-	-	June, 1976
Black-tailed Gnatcatcher Polioptila melanura	X	X	-	X	Apr., June, Aug., 1975
Solitary Vireo Vireo solitarius	-	-	-	X	June, 1975, 1977
Orange-crowned Warbler** Vermivora celata	-	-	-	X	Apr., June, 1975, Apr., 1977
Virginia's Warbler Vermivora virginiae	X	-	-	X	June, 1975
MacGillivray's Warbler Oporornis tolmiei	X	-	-	X	June, 1975, 1976
Wilson's Warbler Wilsonia pusilla	X	-	-	X	Apr., June, Aug., 1975 (Transient: Oct., 1976)
Black-headed Grosbeak Pheucticus melanocephalus	-	-	-	X	June, Aug., 1975, 1976

X Presence

- Absence

*May be summer resident.

**May be transient.

(the blue-gray and black-tailed) were often together, usually fighting, and could be readily distinguished.

The pattern of change in avian abundance is markedly different from the mammalian pattern. Mammalian production begins increasing in spring, continues through the summer, and peaks in the fall. The numbers decrease in winter and repeat the pattern the next year. Avian abundance is keyed to the summer and winter residents; peak populations are present in June and February. Winter abundance has been as low as 166, as high as 896, averaging 416 $\pm$ 240, by far the most variable. Summer abundance has been high as 1510, as low as 983, averaging 1162 $\pm$ 174. The least variable abundance is during the April migration, averaging 506 $\pm$ 46. In August there is a consistent decrease in abundance, averaging 616 $\pm$ 137. Avian abundance in June through the years has consistently been the highest ($n = 48, \alpha = .05, F = 3.2302$) Table 64). Also, the riparian vegetation is where most of the birds reside ($n = 48, \alpha = .05, F = 7.1372$), followed by the sagebrush-greasewood, the juniper, and lastly, the shadscale (Figure 69). Abundance in 1975 and 1976 are quite similar, 3036 and 3099, respectively. In 1977 avian abundance declined to 1965.

<u>Amphibians and Reptiles</u>

The reptiles and amphibians are all permanent residents of the oil shale tract. None of 15 species recorded during the Baseline assessment usually undertake substantial movements. All are inactive during the winter months, generally from October through April. However, this is variable, since inactivity and emergence are keyed to climatic conditions.

There are four species of amphibians on the tract (Table 65): the great basin spadefoot toad, Woodhouse's toad, the leopard frog, and the chorus frog. These vertebrates are found primarily along the White

Table 64. The number of avian species and their abundance according to year and sampling period combining all vegetation types.

Year	February		April		June		August	
	Species No.	Abundance From Transects	Species No.	Abundance From Transects	Species No.	Abundance From Transects	Species No.	Abundance From Transects
1975	20	166	65	521	81	1510	55	839
1976	29	896	58	578	78	983	61	642
1977	22	186	59	419	68	993	52	367
Mean	24 ± 3	416 ± 240	61 ± 2	506 ± 46	76 ± 4	1162 ± 174	56 ± 3	616 ± 137

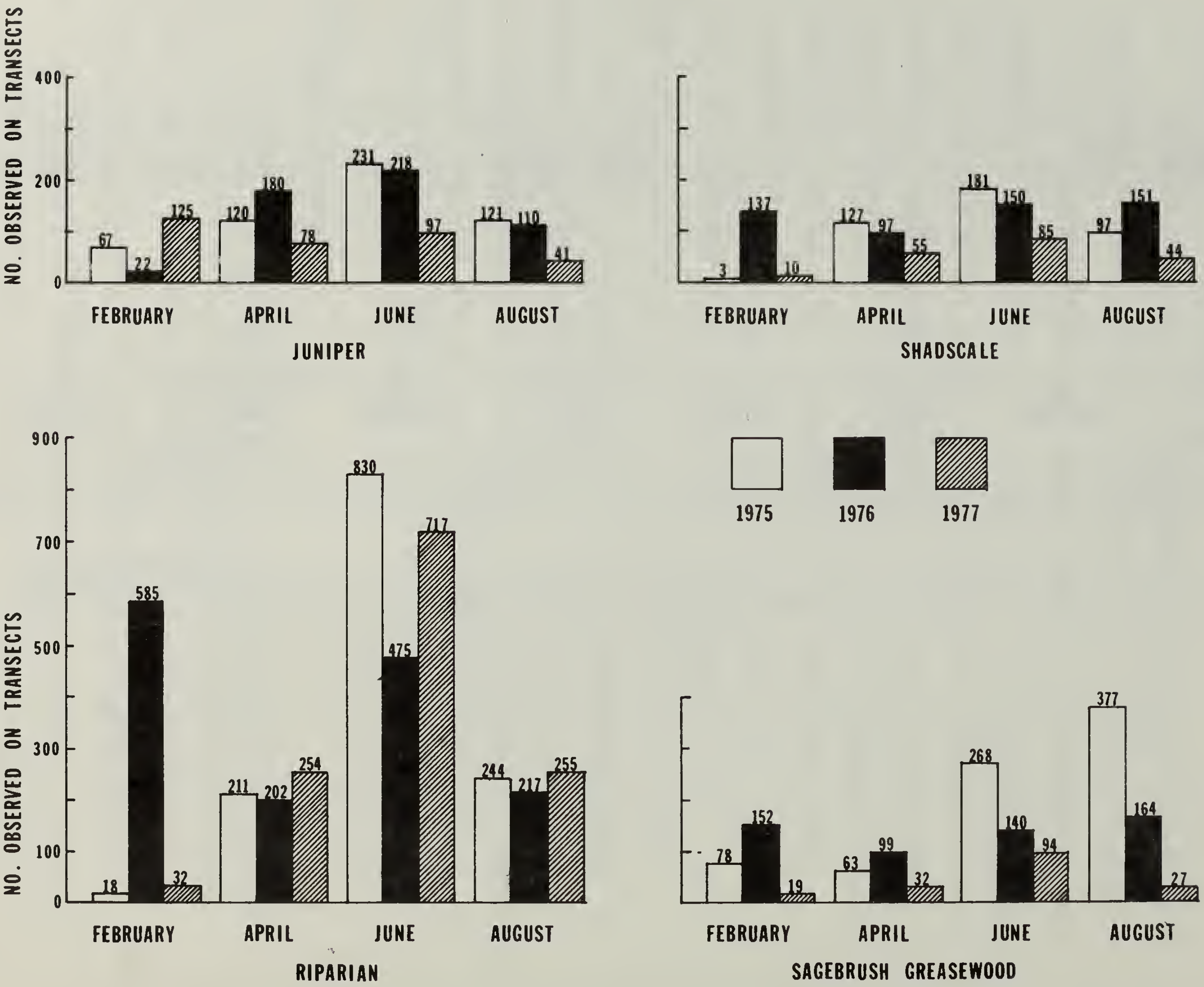


Figure 69. Avian abundance in four vegetation types for three consecutive

Table 65. Reptiles and amphibians observed on the Oil Shale Tracts for three consecutive years, 1975-1977.

Class/Order/Species	Class/Order/Species
AMPHIBIA	
Anura	
Great Basin Spadefoot Toad *Scaphiopus intermontanus*	Leopard Frog *Rana pipiens*
Woodhouses (Rocky Mt.) Toad *Bufo woodhousei*	Chorus Frog *Pseudacris triseriata*
REPTILIA	
Squamata (Suborders Lacertilia, Lizards and Serpentes, Snakes)	
Eastern Fence Lizard *Sceloporous undulatus*	Racer *Coluber constrictor*
Sagebrush Lizard *Sceloporous graciosus*	Striped Whipsnake *Masticophis taeniatus*
Side-blotched Lizard *Uta stansburiana*	Gopher Snake *Pituophis melanoleucus*
Tree Lizard *Urosaurus ornatus*	Western Garter Snake *Thamnophis elegans*
Short-horned Lizard *Phrynosoma douglassi*	Midget Faded Rattlesnake *Crotalus viridus*
Western Whiptail *Cnemidophorous tigris*	

River, but also sporadically inhabit areas that have some permenent moisture, e.g., Asphalt Wash gas pond. The spadefoot toad is the only species of the four that does not require substantial standing water. This animal is adapted to life in an arid environment and can tolerate excessive drought by burrowing to subterranean moisture sources.

From the qualitative, daytime observations, none of the amphibian species appear to be common. This is probably biased as a result of a sampling program that cannot consider restrictive amphibian behavior. Amphibian abundance appears to be the highest in June of all the sample years. This is also the period where all of the species are observed. This is a direct response to the widespread availability of water. As summer progresses and the emphemeral water evaporates, the likelihood of observation is essentially restricted to one or two species in the riparian habitat. The leopard frog and an occasional Woodhouse's toad are the only amphibians recorded during the August sampling periods.

There are 11 species of reptiles, six lizards, and five snakes that have been observed on tract during 1975-1977 (Table 65). The greatest abundance of lizards occurs in the juniper ($n = 24, \alpha = .05$, $F = 4.3254$) Figure 70). The dramatic increase in lizards in the June 1977 shadscale sample is probably due to the new shadscale sampling site (WS-4). However, the August 1977 sample is the shadscale is not out of line when compared to August 1975 and 1976. The June 1977 increase is attributed to two species, the side-blotched lizard and western whiptail (Table 66) who remained uncommon on the WS-1 transect, yet abundant on the WS-4 transect.

The eastern fence and the sagebrush lizards have been consistent in number and distribution through three years (Table 66). Tree lizards have

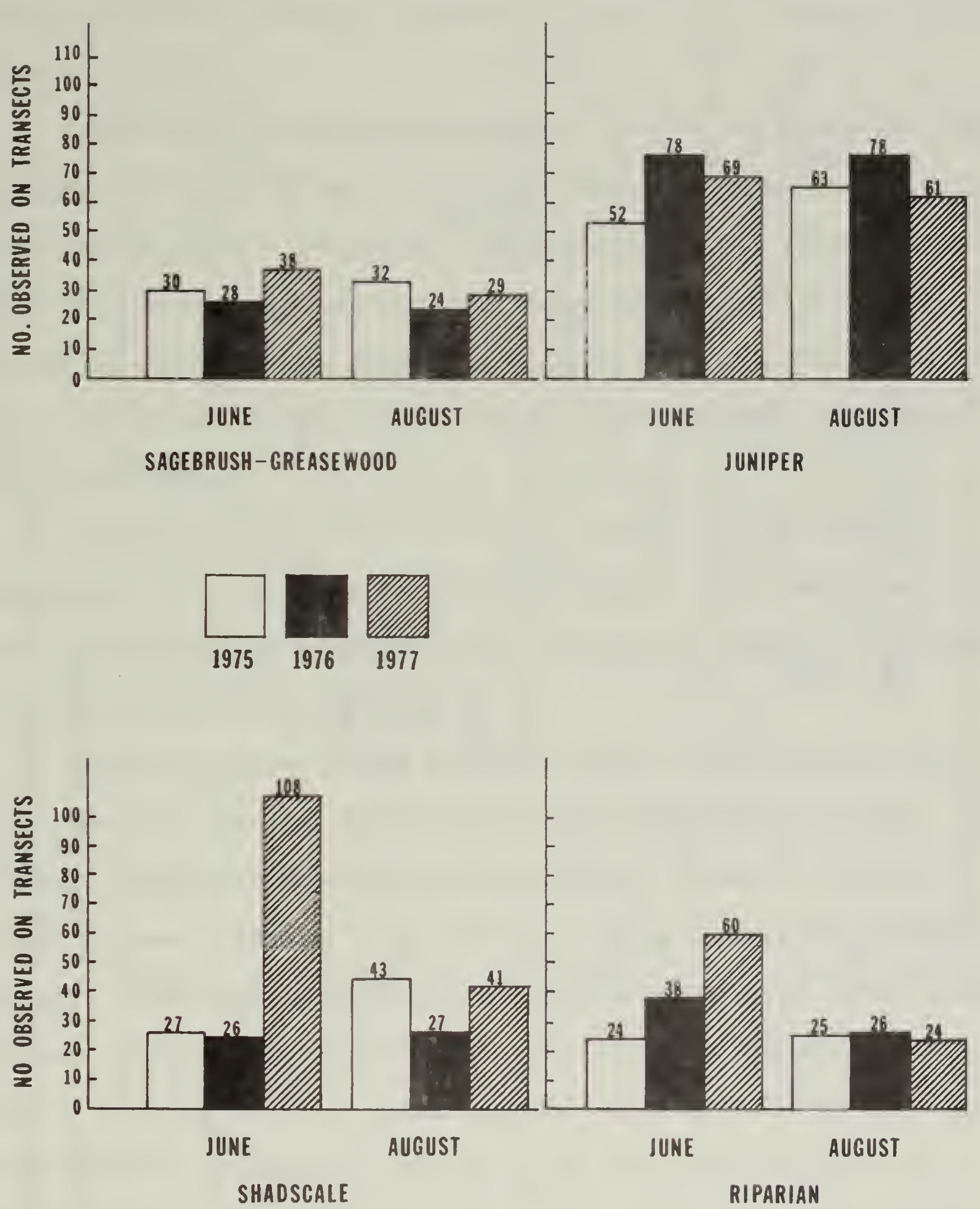


Figure 70. Reptilian abundance in four vegetation types for three consecutive years on the Utah Oil Shale Tracts. Abundance was determined from flushing transects.

Table 66. Annual reptilian abundance by habitat type, numbers and percent on the Utah Oil Shale Tracts.

Species	1975 No. Obs.	1975 S-G [1]	1975 J	1975 S	1975 R	1976 No. Obs.	1976 S-G	1976 J	1976 S	1976 R	1977 No. Obs.	1977 S-G	1977 J	1977 S	1977 R
E. Fence Lizard	27	2 (7)[2]	15 (56)	1 (4)	9 (33)	19	1 (5)	8 (42)	0	10 (53)	24	0	7 (29)	6 (25)	11 (46)
Sagebrush Lizard	181	38 (21)	67 (37)	55 (30)	21 (12)	194	31 (16)	83 (43)	51 (26)	29 (15)	160	50 (31)	46 (29)	46 (29)	18 (11)
Side-blotched Lizard	27	3 (11)	17 (63)	5 (19)	2 (7)	47	8 (17)	38 (81)	0	1 (2)	124	0	52 (42)	56 (45)	16 (13)
Tree Lizard	1	0	1 (100)	0	0	9	0	6 (67)	0	3 (33)	11	0	6 (55)	0	5 (45)
Short-horned Lizard	9	0	0	9 (100)	0	2	0	0	2 (100)	0	2	1 (50)	0	1 (50)	0
Western Whiptail	37	15 (41)	15 (41)	0	7 (18)	50	11 (22)	20 (40)	0	19 (38)	104	16 (15)	19 (18)	38 (37)	31 (30)
Racer	4	0	0	0	4 (100)	1	0	0	0	1 (100)	0	0	0	0	0
Striped Whipsnake	3	2 (67)	0	0	1 (33)	1	0	0	0	1 (100)	3	0	0	2 (67)	1 (33)
Gopher Snake	2	0	0	0	2 (100)	0	0	0	0	0	0	0	0	0	0
Garter Snake	2	0	0	0	2 (100)	0	0	0	0	0	2	0	0	0	2 (100)
Faded Midget	2	2 (100)	0	0	0	2	1 (50)	1 (50)	0	0	0	0	0	0	0
Rattlesnake															
Total	295	62	115	70	48	325	52	156	53	64	430	67	130	149	84
%		21	39	24	16		16	48	16	20		16	30	35	19

[1] S-G - Sagebrush-greasewood, J - Juniper, S - Shadscale, R - Riparian.

[2] Numbers in parentheses are the percent of each species observed in a habitat type.

shown a slight increase and short-horned lizards, a slight decrease. Tree lizard abundance may be low due to their vertical distribution. The decrease in short-horned lizards (horned toads) is attributed to the decrease in ant activity in 1976 and 1977. Abundance of side-blotched lizards and western whiptails remained consistent in all vegetation types except the shadscale.

Lizards are by far the most abundant reptiles and snakes the least. The sagebrush lizard has been consistently the most commonly sighted species in all habitat types. The greatest concentration of all lizard species, except the short-horned, was recorded in the juniper habitat type. Considering overall lizard abundance, no major changes have occurred in lizard populations, within each of the major habitat types, during the monitoring program.

The observations of snakes are very limited and are generally opportunistic. Snakes are not normally evident in their environment and have a low probability of observation. The majority (64%) of observations are from the riparian habitat type.

Reptilian species occupy different areas in the various habitat types. Eastern fence and tree lizards are associated with elevated, often vertical, surfaces such as trees, rock outcrops, and walls. Sagebrush lizards are most commonly found near one of the desert shrubs, although they will utilize open rock faces and the lower portions of trees. Side-blotched lizards occupy flat rock and open, sparsely vegetated ground within all of the habitats. Short-horned lizards were most often sighted in the more open shadscale community, while the western whiptails, although widespread, are most commonly seen near greasewood (*Sarcobatus vermiculatus*).

The racer and qarter snakes are restricted to the riparian area along the White River. Neither species, in particular the garter snake, can tolerate extremely dry areas. Gopher snakes are found in all habitat types. The whipsnake prefers grass, brushland, and sage flats with rock outcroppings. Rattlesnake observations are generally confined to the sagebrush-greasewood draws. However, this species occupies a variety of habitats, with the exception of the White River bottomland.

A relatively complete review of the pertinent literature concerning on-tract reptiles is available in the 1977 Final Environmental Baseline Report (Anon., 1977). Reference is made to that review for additional background information.

4.3.2.4 Interpretation. The two objectives of the continuing monitoring programs are aimed at:

1. Providing information concerning the natural change or stability present in the terrestrial vertebrates; and
2. Providing information that allows for monitoring change or stability in the vertebrates due to mining development, operation, and rehabilitation on the oil shale tract.

Those animals who change as the environment changes provide information essential to achieving the first objective. Those animals who remain stable through environmental change provide information essential to achieving the second goal.

Change and stability are recognizable in four vertebrate attributes: inventory, spatial distribution, temporal distribution, and abundance or density.

The structure of the terrestrial vertebrates is first defined by species inventory. The inventory provides information on stability. There have been seventy-six species of birds consistently present through three years of natural environmental change. There have been nineteen mammalian species, four amphibians, and seven reptiles who have also been consistently present. The use of a consistent inventory is in "presence-absence" information as applied to potential impacts in mining development, operation and rehabilitation. The most stable inventory is in the amphibians and reptiles who have neither added nor lost a representative, followed by the mammals and then the birds.

The second attribute in the structure of terrestrial vertebrates is temporal distribution. The short activity period during fair conditions, and long dormancy periods during harsh conditions, explain why the amphibian and reptilian inventories are so stable. The permanent mammals are second in terms of resident stability, since some species can also go into dormancy but for a short time. Permanent birds are last in lien with only thirteen representatives who must tolerate whatever the temporal changes bring. However, the majority of the birds, due to their mobility, can exploit sections of an annual cycle and move on when conditions change. For this reason, the birds, summer resident, winter residents, and transients, are the primary indicators of change in an annual cycle.

The third attribute is spatial distribution, specifically distribution by vegetation types, although soil and rock characteristics can also be critical. Some animals are specific to a vegetation type; some are found in all vegetation types.

Adding in the fourth attribute, abundance or density allows for definition of species indicating change or stability.

Combining the four attributes, the prime indicators of change due to development are those animals who are permanent residents. Among the avian permanent residents, the indicator species for the sagebrush-greasewood and the shadscale is the loggerhead shrike. Although shrikes are low in number, they are consistently present. Their carniverous habits reflect the status of the prey base in these two vegetation types. The horned lark is a specific indicator for the shadscale vegetation, especially during the winter. They reflect the seed production in this area. Both of these birds reflect stability in their presence and change by their abundance.

The prime indicator of stability in the juniper vegetation is the plain titmouse, whereas the prime indicator of change is the pinon jay. In the riparian vegetation, indicators of stability are the black-capped chickadee and the hairy and downy woodpeckers. Indicative of change is the common flicker.

Indicative of tract-wide stability by their presence are the golden eagle, the great horned owl, and the black-billed magpie. Their abundance reflects tract-wide change.

The rodent species indicative of stability both in presence and density are the Apache pocket mouse and the Ord kangaroo rat in the sagebrush-greasewood and shadscale vegetation types. Change in these two vegetation types are reflected by the whitetailed antelope squirrel and, of course, the deer mouse. In the juniper vegetation, stability is indicated by the presence of the least chipmunk, the canon mouse, and the desert woodrat. Change is indicated by density fluctuations of the above and by deer mice, pinon mice, and bushytailed woodrats. Stability indicators in the riparian vegetation relies upon the beaver and the porcupine. Change is indicated by the eruptive but ever-present deer mouse.

Two other species whose presence is important are the whitetailed prairie dogs in the shadscale vegetation and the western harvest mice present in sagebrush-greasewood and riparian areas. Although the former are restricted to a town and the latter are few in number, both reflect stable characteristics of the tract.

Two mammals reflect tract-wide stability by their presence, change by their abundance. These are the desert cottontails and the mule deer.

Amphibians are indicative of stability by their presence and their limited spatial distribution along the White River. Indicative of change is their temporal distribution; their above-ground activity is keyed to change in the annual cycle.

Reptilians, specifically the lizards, provide the most reliable basis for stability on the tract. Their inventory, spatial distribution, and abundance has remained constant. Their temporal distribution indicates some change in tract conditions. The snakes are indicative of stability by their presence alone and by spatial distribution of the racer and the garter snake being quite specific to the White River area. Snake abundance is indicative of the trends in most insectivorous and carniverous predators throughout the tract; there are so few that their presence is the only reliable factory is assessing change or stability.

4.3.2.5 Summary. 1975 consisted of a cold, wet winter and spring. This led to a high production of annual plants in the spring and significant growth in perrenial plants in the fall. Invertebrates, though not sampled, also bloomed according to qualitative monitoring. As these two energy sources bloomed, so did the birds, reaching their highest abundance and

most diverse number of species in June 1975. During this time rabbit and rodent populations were low, and the lizards appeared to be the most abundant vertebrates on the tract.

In 1976 the winter was mild. It remained cold but lacked the moisture seen in the previous winter. An important point is that precipitation in 1975 and 1976 did not differ in amount but did differ in distribution. The mild winter led to a seven-fold increase in bird abundance (February 1976), specifically among the seed-eating birds. The spring of 1976 was dry and warm. Bird numbers decreased in June 1976, and cottontails and rodents erupted by August 1976. Yet in the same period, plant production was down, as were the invertebrates.

In 1977 the winter was especially mild, as was the spring. Few birds were present in the winter. In June 1977, bird populations continued to decline. In August 1977, rodent populations, specifically the deer mouse, had declined percipitously, whereas cottontail populations declined slightly. Again, plant production was low in 1977; as it appeared, so were invertebrates.

During all these changes in mammals and birds, the lizards remained stable and apparently the most abundant vertebrates on the tract.

After three years of monitoring, some terrestrial vertebrates provide indices to environmental change and other provide indices to measure potential impacts.

4.3.3 Aquatic Biology

WRSP is not conducting any aquatic studies during the interim period. WRSP is, however, following the progress of ongoing USGS aquatic studies. The results of their work were not available at the time this report was printed.

LITERATURE CITED

Anderson, R. D. 1975. Vertebrates. In R. S. Shinn, R. D. Anderson, M. Merritt, W. Osborne, and J. A. MacMahon (Coordinator), Curlew Valley Validation Site Rept. US/IBP Desert Biome Res. Memo. 75-1. Utah State University, Logan. pp. 48-60.

Anonymous. 1977. Final Environmental Baseline Report. Federal Prototype Oil Shale Leasing Program, White River Shale Project. VTN Colorado, Inc.

Armstrong, D. M. 1972. Distribution of Mammals in Colorado. Mongr. Mus. Nat. Hist. No. 3. University of Kansas.

Balph, D. G. et al. 1974. Curlew Valley Site. Desert Biome Research Memorandum. 74-1. Logan: Utah State University.

Barbour, R. W. and W. H. Davis. 1969. Bats of America. Lexington: University of Kentucky.

Behle, W. H. and M. L. Perry. 1975. Utah Birds: Checklist Seasonal and Ecological Occurrence Charts and Guides to Bird Finding. Salt Lake City: Utah Museum of Natural History.

Burt, W. H. and R. P. Grossenheider. 1964. A Field Guide to the Mammals. Boston: Houghton Mifflin Company.

Durrant, S. D. 1952. Mammals of Utah. Lawrence: University of Kansas.

Jennrich, R. L. and F. B. Turner. 1969. Measurement of noncircular home range. J. Theoret. Biol. 22:227-237.

Murie, O. J. 1975. A Field Guide to Animal Tracks. 2nd ed. Boston: Houghton Mifflin Company.

Olsen, P. F. 1973. Wildlife Resources of the Utah Oil Shale Area. Utah Div. Wildl. Resources, Publ. No. 74-2.

Perry, M. L. 1975. Non-game mammal inventory of the Utah Oil Shale Area. In Studies for Wildlife on Energy Areas. BLM and Utah DWR. 50 pp.

Ranck, G. L. 1961. Mammals of the East Tavaputs Plateau. M.S. Thesis, Univ. Utah, 229 pp.

Steele, R. G. D. and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc. New York.

Section 5.0

REVEGETATION RESEARCH PROGRAM

In 1975 the Range Science Department of Utah State University was placed under contract to investigate revegetation techniques for processed shale as well as rehabilitation of disturbed sites. Dr. C. M. McKell is the principal investigator. The work will be completed by January 1, 1979.

5.1 Objectives

The objective of this research is to develop a technology for revegetating disturbed sites and processed shale disposal areas.

5.2 Results to Date

Two reports were prepared during 1977 concerning progress of the research work. This section summarized findings presented in these reports.

5.2.1 Highlights of Fifth Progress Report

A. An Overview of the Period January 1 to June 30, 1977

During the period from January 1 to June 30, 1977 the unusual drought conditions experienced in the previous year continued. This drought accentuated the normally harsh environmental conditions that exist in the oil shale region of eastern Utah. Very few annual plants germinated in the spring of 1977, and weaker seedling of perennial shrubs and forbs failed to survive. The drought undoubtedly reduced the number of rodents but those surviving were forced to eat less palatable plants or parts of plants. Thus, it is common to see bark on stems of greasewood,

rabbitbrush and spiny horsebrush gnawed away by small rodents. Green twigs of rabbitbrush and the succulent but spiny pads of pricklypear cactus have also been extensively utilized by rodents for food and water.

Obtaining satisfactory field research results under such conditions has required greater care than usual but has given us both caution and confidence in making interpretations and applications from our data. Some experiments have not provided the expected results and will require either modifications or additional time. We are making such adjustments in our research plans.

Results from studies that have been completed are beginning to be prepared and reported publicly. Two papers were presented at the Society for Range Management meetings in Portland, Oregon. An invitational paper was presented at the annual meeting of the American Academy for the Advancement of Science in Denver, Colorado. The latter paper was an update of the revegetation concept prepared to accompany the Detailed Development Plan. Other manuscripts are in various stages of preparation.

B. Propagation of Native Plants and Container Problems

Following upon our work in propagating some of the more common and useful (for forage and wildlife habitat) shrubs, we began studies on other native species that would be useful in rehabilitation plantings. Some results have been satisfactory while others indicate that the season of the year may be highly critical in getting plants to produce roots on cuttings. Use of a rooting hormone, indole-butyric acid (IBA), is also essential to promote rooting.

The size and shape of containers used in the greenhouse for holding the seedlings or cuttings is also important. Field survival of container-grown plants was best for those grown in milk cartons as contrasted with

poor survival of plants grown in smaller containers. Root and top growth are to be measured upon the excavation of plants in early July 1977. Indol butyric acid (IBA) or other root-promoting hormones appear to be necessary in rooting cuttings of many native shrubs.

C. Physiological Studies of Plants Grown in Saline Soils

Tolerance to salinity is a key factor in the plan to use native plants for rehabilitating processed oil shale disposal areas. Reduced moisture availability and mineral nutrition are affected by salinity. Saltbush species are particularly adapted to high salinity levels. Salinity levels ranging from 8 to 17 mmhos/cm did not reduce yields of four saltbush species. Yield was reduced by half under a 38 mmhos/cm treatment. Mineral content varied with each species insofar as their uptake of sodium, potassium, calcium, magnesium and phosphorus.

Tolerance of cuneate saltbush to sodium sulfate (Na_2SO_4) and magnesium sulfate ($MgSO_4$), the predominate salts in processed oil shale, is not equal. Sodium in leaves of the saltbush decreased with increasing levels of $MgSO_4$. Potassium increased with increasing levels of both salts. Although MgSO4 had a greater effect, neither salt had any differential effect on nitrogen uptake.

D. Rehabilitation Plantings on Disturbed Sites

Persistence of plantings made in 1975, 1976 and spring of 1977 was evaluated in June 1977. Drought conditions coupled with intense utilization by sheep and small mammals had an adverse effect on plant survival - more so in some sites than others. Sagebrush and fourwing saltbush appear to have the best survival in the 1975 planting.

Some shrubs such as greasewood, fourwing saltbush, winterfat, and rabbit brush will reproduce a few small seedlings from fall or spring direct seeding in a favorable year. However, an overall survival rate of 66 percent from transplanting bare root or container-grown plants is a far better result than those from direct seeding in terms of stand success and survivability. Grass transplants appear to have a higher survival rate from spring rather than fall planting.

Transplanting of shrub, forb and grass seedlings into large boxes filled with Paraho processed shale has given mixed results. Survival has been low for transplants in straight shale but exceptionally good results have been obtained where the shale was overlain with soil. Deference of planting on shale to the second year appears to be better than immediately after the shale is laid down.

E. Salt Movement and Chemical Weathering in Process Shale

Columns of processed shale were exposed over winter to the influence of wetting-drying and freezing-thawing. There was an increase in the percentage of fine particles at the surface in Paraho processed Colorado shale and a decrease in fine particles in the Paraho Utah shale and Union Utah shale indicating some particle migration in the latter two.

Electrical conductivity of Paraho Colorado shale was lower at greater depths and decreased with an increase in particle size. In Paraho Utah shale and Union Utah shale there was an increase in EC with depth.

Chemical weathering occurs faster in the smaller particles and at the shallower depth as indicated by reduced pH values for smallest particle size fractions and lower pH values near the surface. In a more normal precipitation year, chemical weathering would be expected to be more pronounced.

F. Pilot Model and Water Harvesting Studies

Due to the low amount of precipitation during the fall, winter and spring months, no leaching through the pilot model occurred. Simulated rainfall events must be considered if we are to obtain any data from the model. Several species of plants were planted in the topsoil trench of the pilot model in April.

Of the two soil surface stabilizing materials tested in the water catchment basins, the SBR (Styrene butadiene latex) material was far more effective and resistant to degradation than DCA-70 (polyvinyl acetate).

5.2.2 Highlights of Sixth Progress Report

A. An Overview of the Period July 1 to December 31, 1977

Although the second half of 1977 was not as dry as the first part, the impact of the dry winter of 1976-77 and dry spring was observed in results from a number of experiments. Plant survival was reduced in our plantings on disturbed sites, the degree of success observed in our out-plantings of three shrub species grown in various types of containers was less than previous experience led us to expect, and our plans to collect leachate, observe water and salt movement and possible water harvesting on the pilot model of an oil shale disposal pile were thwarted by lack of precipitation. Many experimental plans had to be modified to meet the realities of extreme weather variability. In many ways the year of low rainfall can be considered a benefit, however. Our success in obtaining plant growth, plant survival, water use efficiency, shale weathering and other results under such limited conditions justified the general approach we have outlined for rehabilitation of disturbed sites and processed shale.

B. <u>Propagation of Native Plants and Container Problems</u>

Two important objectives were achieved in the past six months in the area of plant propagation. Eduardo Alvarez and Jerry Barker each completed their work on plant propagation.

The main findings of the Alvarez work are that big sagebrush can be propagated successfully by choosing plants with high rootability and taking stem tip cuttings while plants are still dormant. Root hormone application levels higher than routinely used in the Horticultural industry are necessary.

Mr. Barker found that container size and shape were important in propagating plant materials for outplanting to the field. Containers the size of milk cartons will produce larger plants (both tops and roots) than small containers the size of the single cell units. Field survival of plants was higher for plants grown in large containers than those grown in small containers. If given sufficient time to grow after removal from containers, most plants will overcome the effect of constraints imposed by the containers.

In further studies on the methods of propagating the important saltbush species, larger stem cuttings of fourwing saltbush were found to root better than smaller cuttings, and cuttings from the basal portions of new leader growth rooted better than cuttings from the tips of leaders.

C. <u>Physiological Studies</u>

The high salt tolerances of several saltbush species have been demonstrated in past reports. Further information is needed on the salt tolerances of other plant species. An experiment included in this report shows the much lower tolerances of spiny hopsage and black sagebrush as compared with shadscale saltbush. Increasing soil or shale salinity will restrict the number of plant species that can be successfully established.

In addition to the requirements for nitrogen and phosphorous fertilization of processed oil shale for plant growth, added potassium can enhance growth of species such as fourwing saltbush. Of particular interest is the greater stimulation of root growth than shoot growth by potassium. Rapid root growth is extremely important for survival of transplants on shale or disturbed soils. The growth stimulation by added potassium occurred at high and low soil moistures and at high and low salinity levels.

D. Rehabilitation Plantings on Disturbed Sites

Plant survival continued to decline from field plantings made in 1975 and 1976 because of the severe drought and rodent damage apparently exacerbated by the lack of feed and succulent stems caused by the drought.

Range scientists who visited the research site in the early fall (September) were impressed with the amount of plant growth and survival that we had been able to obtain through the dry period.

E. Water Harvesting from a Saline Medium

One of the most serious problems envisioned from water harvesting in an arid region or from a saline material such as oil shale is the possibility of harvesting salts along with water. A study funded by a grant from the U.S. Department of Agriculture (USDA) was initiated in October 1977 to determine the magnitude of salinity in runoff and leachate from processed oil shale. Two experiments using shale-filled boxes will be conducted at the Utah Water Research Laboratory (USU) using an elaborate rainfall simulator. A third experiment will be conducted at the Anvil Points oil shale retort facility on the compacted oil shale pile.

Some indication of salinity content of harvested water was obtained from results of simulated rainfall application to the WRSP pilot model in August 1977. Electrical conductivity (salinity) of runoff water was more than double that of tap water.

F. Weathering of Processed Oil Shale

Two studies of oil shale weathering indicate that the freezing - thawing action on processed oil shale breaks up large particles into smaller particles along cleavage lines. Field weathering causes a reduction in Ec of surface particles and an increase in the proportion of smaller particles.

G. Pilot Model and Associated Studies

The pilot model of a shale disposal pile which is located in the Section 6 research site was subjected to simulated rainfall of about 25 cm (10 inches) in August. Runoff and leachate were collected for laboratory analysis. Measurements of changes in moisture and salinity inside the model were made through the use of sensors placed there at the time the model was constructed.

H. Research Plans

Emphasis in research activities in 1978 will shift from field and laboratory research to writing of reports, technical manuscripts and a manual of recommended practices for rehabilitation of processed oil shale and disturbed arid sites. Even so, several priority studies that were planned in the later half of 1977 will be implemented along with completing ongoing studies.

- APPENDIX A -

Joint Frequency Distributions at Site A6

Interim Year - 1977

Example

Vertical atmospheric stability class 1 and σ_θ stability class A

Vertical atmospheric stability

Wind direction

north = 1

Wind Speed

CLASSIFICATION 1A

ST	WD	0-1.4	1.5-3.4	WS (m/s) 3.5-5.5	5.6-7.9	≥ 8.0	TOTAL
1	1	.000400	.000000	.000000	.000000	.000000	.000400
1	2	.000000	.000000	.000000	.000000	.000000	.000000
1	3	.000000	.000000	.000000	.000000	.000000	.000000
1	4	.000000	.000000	.000000	.000000	.000000	.000000
1	5	.000000	.000000	.000000	.000000	.000000	.000000
1	6	.000000	.000000	.000000	.000000	.000000	.000000
1	7	.000000	.000000	.000000	.000000	.000000	.000000
1	8	.000000	.000000	.000000	.000000	.000000	.000000
1	9	.000000	.000000	.000000	.000000	.000000	.000000
1	10	.000000	.000000	.000000	.000000	.000000	.000000
1	11	.000000	.000000	.000000	.000000	.000000	.000000
1	12	.000000	.000400	.000000	.000000	.000000	.000400
1	13	.000000	.000400	.000000	.000000	.000000	.000400
1	14	.000000	.000000	.000000	.000000	.000000	.000000
1	15	.000400	.000000	.000000	.000000	.000000	.000400
1	16	.000000	.000000	.000000	.000000	.000000	.000000
TOTAL		.000800	.000800	.000000	.000000	.000000	.001600

Vertical Atmospheric Stability

1 = Unstable or neutral

2 = Slightly stable

3 = Very stable

All parameters were measured at 30 meters above ground, except that ΔT was measured between 10 and 30 meters.

CLASSIFICATION 1A

ST	WD	WS (m/s) 0 - 1.4	1.5 - 3.4	3.5 - 5.5	5.6 - 7.9	≥ 8.0	TOTAL
1	1	.000100	.000000	.000000	.000000	.000000	.000100
1	2	.000000	.000000	.000000	.000000	.000000	.000000
1	3	.000000	.000100	.000000	.000000	.000000	.000100
1	4	.000000	.000000	.000000	.000000	.000000	.000000
1	5	.000000	.000000	.000000	.000000	.000000	.000000
1	6	.000000	.000000	.000000	.000000	.000000	.000000
1	7	.000000	.000000	.000000	.000000	.000000	.000000
1	8	.000000	.000000	.000000	.000000	.000000	.000000
1	9	.000000	.000000	.000000	.000000	.000000	.000000
1	10	.000000	.000000	.000000	.000000	.000000	.000000
1	11	.000000	.000000	.000000	.000000	.000000	.000000
1	12	.000000	.000100	.000000	.000000	.000000	.000100
1	13	.000000	.000200	.000000	.000000	.000000	.000200
1	14	.000000	.000000	.000000	.000000	.000000	.000000
1	15	.000100	.000000	.000000	.000000	.000000	.000100
1	16	.000100	.000000	.000000	.000000	.000000	.000100
TOTAL		.000300	.000400	.000000	.000000	.000000	.000700

CLASSIFICATION 1B

WS (m/s)

ST	WD	0-1.4	1.5-3.4	3.5-5.5	5.6-7.9	≥ 8.0	TOTAL
1	1	.000200	.000400	.000100	.000000	.000000	.000700
1	2	.000500	.000300	.000000	.000000	.000000	.000800
1	3	.000100	.000100	.000000	.000000	.000000	.000200
1	4	.000200	.000300	.000000	.000000	.000000	.000500
1	5	.000100	.000100	.000000	.000000	.000000	.000200
1	6	.000100	.000000	.000000	.000000	.000000	.000100
1	7	.000000	.000100	.000000	.000000	.000000	.000100
1	8	.000000	.000200	.000000	.000000	.000000	.000200
1	9	.000000	.000000	.000000	.000000	.000000	.000000
1	10	.000100	.000000	.000000	.000000	.000000	.000100
1	11	.000000	.000200	.000000	.000000	.000000	.000200
1	12	.000200	.000600	.000100	.000000	.000000	.000900
1	13	.000100	.001100	.000300	.000000	.000000	.001500
1	14	.000300	.001200	.000400	.000000	.000000	.001900
1	15	.000800	.003500	.000200	.000000	.000000	.004500
1	16	.000200	.001300	.000100	.000000	.000000	.001600
TOTAL		.002900	.009400	.001200	.000000	.000000	.013500

CLASSIFICATION 1C

ST	WD	WS (m/s) 0-1.4	1.5-3.4	3.5-5.5	5.6-7.9	≥ 8.0	TOTAL
1	1	.001200	.005200	.000300	.000100	.000000	.006800
1	2	.000800	.001900	.000000	.000000	.000000	.002700
1	3	.000200	.002100	.000300	.000000	.000000	.002600
1	4	.000300	.001800	.000200	.000000	.000000	.002300
1	5	.000400	.001100	.000100	.000000	.000000	.001600
1	6	.000400	.000800	.000000	.000000	.000000	.001200
1	7	.000100	.000600	.000100	.000000	.000000	.000800
1	8	.000300	.000300	.000200	.000000	.000000	.000800
1	9	.000000	.000600	.000500	.000100	.000000	.001200
1	10	.000100	.000800	.001300	.000500	.000100	.002800
1	11	.000300	.001800	.000800	.000500	.000000	.003400
1	12	.000300	.002200	.001300	.000400	.000100	.004300
1	13	.001300	.007400	.001800	.000100	.000000	.010600
1	14	.002700	.016600	.004000	.000200	.000000	.023500
1	15	.002700	.018900	.004100	.000000	.000000	.025700
1	16	.001600	.008600	.000600	.000000	.000000	.010800
TOTAL		.012700	.070700	.015600	.001900	.000200	.101100

CLASSIFICATION 1D

ST	WD	0-1.4	1.5-3.4	3.5-5.5	5.6-7.9	≥8.0	TOTAL
				WS(m/s)			
1	1	.001300	.005300	.000900	.000300	.000000	.007800
1	2	.001300	.002000	.000400	.000100	.000000	.003800
1	3	.001700	.003300	.000500	.000500	.000000	.006000
1	4	.001100	.002100	.001000	.000600	.000000	.004800
1	5	.001300	.002400	.001100	.000000	.000000	.004800
1	6	.001100	.000800	.000200	.000000	.000000	.002100
1	7	.001100	.001600	.000900	.000000	.000000	.003600
1	8	.000800	.001300	.000800	.000500	.000300	.003700
1	9	.000600	.002000	.002400	.004700	.004300	.014000
1	10	.000400	.001300	.001800	.004100	.006600	.014200
1	11	.000900	.001600	.002100	.005900	.004400	.014900
1	12	.000900	.001700	.002500	.003400	.001800	.010300
1	13	.001300	.007700	.006300	.005300	.001000	.021600
1	14	.001700	.016000	.011400	.003300	.000300	.032700
1	15	.001700	.010700	.006900	.001700	.000000	.021000
1	16	.001400	.004100	.002800	.000500	.000100	.008900
TOTAL		.018600	.063900	.042000	.030900	.018800	.174200

CLASSIFICATION 1E

ST	WD	WS (m/s) 0-1.4	1.5-3.4	3.5-5.5	5.6-7.9	≥ 8.0	TOTAL
1	1	.000600	.002100	.000800	.001100	.000100	.004700
1	2	.000200	.001200	.000200	.000600	.000000	.002200
1	3	.000500	.002700	.001100	.000300	.000100	.004700
1	4	.000400	.000600	.001300	.000300	.000100	.002700
1	5	.000300	.000900	.001100	.000500	.000400	.003200
1	6	.000300	.000400	.000400	.000000	.000000	.001100
1	7	.000500	.000900	.000400	.000000	.000000	.001800
1	8	.000100	.001900	.002200	.000600	.000100	.004900
1	9	.000400	.001800	.003300	.002400	.002800	.010700
1	10	.000000	.000600	.000400	.000600	.001700	.003300
1	11	.000000	.000600	.000300	.000500	.000400	.001800
1	12	.000200	.000600	.000300	.000900	.000300	.002300
1	13	.000600	.005700	.003800	.005900	.003300	.019300
1	14	.000300	.002500	.004100	.006700	.010200	.023800
1	15	.000500	.002100	.002500	.004400	.002700	.012200
1	16	.000400	.001700	.001400	.001200	.000400	.005100
TOTAL		.005300	.026300	.023600	.026000	.022600	.103800

CLASSIFICATION 1F

ST	WD	WS (m/s) 0-1.4	1.5-3.4	3.5-5.5	5.6-7.9	≥ 8.0	TOTAL
1	1	.000000	.000100	.000000	.000000	.000000	.000100
1	2	.000000	.000000	.000000	.000000	.000000	.000000
1	3	.000000	.000000	.000000	.000000	.000000	.000000
1	4	.000000	.000000	.000000	.000000	.000000	.000000
1	5	.000000	.000000	.000000	.000000	.000000	.000000
1	6	.000000	.000000	.000000	.000000	.000000	.000000
1	7	.000200	.000000	.000000	.000000	.000000	.000200
1	8	.000000	.000300	.000100	.000000	.000000	.000400
1	9	.000000	.000000	.000000	.000000	.000000	.000000
1	10	.000000	.000000	.000000	.000000	.000000	.000000
1	11	.000000	.000000	.000000	.000000	.000000	.000000
1	12	.000000	.000100	.000000	.000000	.000000	.000100
1	13	.000000	.000800	.000200	.000000	.000000	.001000
1	14	.000100	.000600	.000300	.000000	.000000	.001000
1	15	.000000	.000100	.000000	.000000	.000000	.000100
1	16	.000000	.000000	.000000	.000000	.000000	.000000
TOTAL		.000300	.002000	.000600	.000000	.000000	.002900

CLASSIFICATION 2A

		WS (m/s)					
ST	WD	0- 1.4	1.5- 3.4	3.5-5.5	5.6-7.9	≥ 8.0	TOTAL
2	1	.000000	.000100	.000000	.000000	.000000	.000100
2	2	.000100	.000000	.000000	.000000	.000000	.000100
2	3	.000000	.000000	.000000	.000000	.000000	.000000
2	4	.000000	.000000	.000000	.000000	.000000	.000000
2	5	.000000	.000000	.000000	.000000	.000000	.000000
2	6	.000000	.000000	.000000	.000000	.000000	.000000
2	7	.000000	.000000	.000000	.000000	.000000	.000000
2	8	.000000	.000000	.000000	.000000	.000000	.000000
2	9	.000000	.000000	.000000	.000000	.000000	.000000
2	10	.000000	.000000	.000000	.000000	.000000	.000000
2	11	.000000	.000000	.000000	.000000	.000000	.000000
2	12	.000000	.000000	.000000	.000000	.000000	.000000
2	13	.000000	.000000	.000000	.000000	.000000	.000000
2	14	.000100	.000000	.000000	.000000	.000000	.000100
2	15	.000000	.000100	.000000	.000000	.000000	.000100
2	16	.000000	.000100	.000000	.000000	.000000	.000100
TOTAL		.000200	.000300	.000000	.000000	.000000	.000500

CLASSIFICATION 28

		WS (m/s)					
ST	WD	0-1.4	1.5-3.4	3.5-5.5	5.6-7.9	≥ 8.0	TOTAL
2	1	.000100	.000000	.000000	.000000	.000000	.000100
2	2	.000000	.000000	.000000	.000000	.000000	.000000
2	3	.000000	.000000	.000000	.000000	.000000	.000000
2	4	.000000	.000000	.000000	.000000	.000000	.000000
2	5	.000000	.000000	.000000	.000000	.000000	.000000
2	6	.000000	.000100	.000000	.000000	.000000	.000100
2	7	.000000	.000000	.000000	.000000	.000000	.000000
2	8	.000000	.000000	.000000	.000000	.000000	.000000
2	9	.000100	.000000	.000000	.000000	.000000	.000100
2	10	.000100	.000000	.000000	.000000	.000000	.000100
2	11	.000000	.000100	.000000	.000000	.000000	.000100
2	12	.000000	.000000	.000000	.000000	.000000	.000000
2	13	.000000	.000000	.000000	.000000	.000000	.000000
2	14	.000000	.000000	.000000	.000000	.000000	.000000
2	15	.000100	.000200	.000000	.000000	.000000	.000300
2	16	.000000	.000200	.000000	.000000	.000000	.000200
TOTAL		.000400	.000600	.000000	.000000	.000000	.001000

CLASSIFICATION 2C

		ws (m/s)					
ST	WD	0 - 1.4	1.5 - 3.4	3.5 - 5.5	5.6 - 7.9	≥ 8.0	TOTAL
2	1	.000600	.000300	.000000	.000000	.000000	.000900
2	2	.000300	.000400	.000000	.000000	.000000	.000700
2	3	.000500	.000600	.000000	.000000	.000000	.001100
2	4	.000400	.000200	.000100	.000000	.000000	.000700
2	5	.000200	.000400	.000000	.000000	.000000	.000600
2	6	.000100	.000200	.000000	.000000	.000000	.000300
2	7	.000300	.000300	.000000	.000000	.000000	.000600
2	8	.000200	.000600	.000100	.000000	.000000	.000900
2	9	.000500	.000100	.000200	.000000	.000000	.000800
2	10	.000100	.000200	.000000	.000000	.000000	.000300
2	11	.000100	.000200	.000000	.000100	.000000	.000400
2	12	.000000	.000300	.000000	.000000	.000000	.000300
2	13	.000400	.000900	.000000	.000000	.000000	.001300
2	14	.000300	.000900	.000000	.000000	.000000	.001200
2	15	.001300	.001200	.000100	.000000	.000000	.002600
2	16	.000400	.000500	.000000	.000000	.000000	.000900
TOTAL		.005700	.007300	.000500	.000100	.000000	.013600

CLASSIFICATION 2D

ST	WD	ws (m/s) 0-1.4	1.5-3.4	3.5-5.5	5.6-7.9	≥ 8.0	TOTAL
2	1	.001000	.001100	.000300	.000000	.000000	.002400
2	2	.001000	.001000	.000500	.000000	.000000	.002500
2	3	.001000	.001800	.000300	.000000	.000000	.003100
2	4	.001300	.001100	.000300	.000000	.000100	.002800
2	5	.001300	.001800	.000400	.000100	.000000	.003600
2	6	.000900	.001800	.000300	.000100	.000000	.003100
2	7	.001200	.002400	.000200	.000100	.000000	.003900
2	8	.000900	.001300	.000500	.000100	.000000	.002800
2	9	.000400	.002800	.001700	.000400	.000000	.005300
2	10	.000300	.001300	.001000	.000600	.000400	.003600
2	11	.000500	.001700	.001700	.000900	.000200	.005000
2	12	.000300	.001800	.000400	.000200	.000000	.002700
2	13	.000400	.001400	.001200	.000500	.000000	.003500
2	14	.000600	.002800	.000900	.000200	.000000	.004500
2	15	.001000	.001800	.000300	.000000	.000000	.003100
2	16	.000400	.001100	.000300	.000000	.000000	.001800
TOTAL		.012500	.027000	.010300	.003200	.000700	.053700

CLASSIFICATION 2E

Ws (m/s)

ST	WD	0 - 1.4	1.5 - 3.4	3.5 - 5.5	5.6 - 7.9	≥ 8.0	TOTAL
2	1	.000300	.001900	.000800	.000200	.000000	.003200
2	2	.000400	.001300	.000900	.000100	.000000	.002700
2	3	.000400	.002100	.000800	.000300	.000000	.003600
2	4	.000600	.001900	.000500	.001000	.000200	.004200
2	5	.000900	.002400	.001700	.000300	.000300	.005600
2	6	.000400	.002700	.000800	.000100	.000000	.004000
2	7	.002100	.009900	.000300	.000200	.000000	.012500
2	8	.000800	.011200	.010000	.001300	.000000	.023300
2	9	.000900	.009000	.018200	.004400	.000400	.032900
2	10	.000000	.000900	.001600	.001900	.001000	.005400
2	11	.000200	.001900	.001800	.001300	.000200	.005400
2	12	.000100	.000800	.001600	.000500	.000100	.003100
2	13	.000500	.002800	.005100	.002900	.001000	.012300
2	14	.000300	.002400	.003500	.003000	.004400	.013600
2	15	.000100	.003000	.001700	.001700	.000200	.006700
2	16	.000500	.001400	.000800	.000300	.000000	.003000
TOTAL		.008500	.055600	.050100	.019500	.007800	.141500

CLASSIFICATION 2F

		WS (m/s)					
ST	WD	0-1.4	1.5-3.4	3.5-5.5	5.6-7.9	≥ 8.0	TOTAL
2	1	.000000	.000200	.000000	.000000	.000000	.000200
2	2	.000000	.000100	.000000	.000000	.000000	.000100
2	3	.000000	.000200	.000000	.000000	.000000	.000200
2	4	.000200	.000200	.000000	.000000	.000000	.000400
2	5	.000200	.000100	.000000	.000000	.000000	.000300
2	6	.000300	.000000	.000000	.000000	.000000	.000300
2	7	.000100	.000800	.000000	.000000	.000000	.000900
2	8	.000300	.002000	.001100	.000300	.000000	.003700
2	9	.000000	.000200	.000300	.000000	.000000	.000500
2	10	.000100	.000000	.000000	.000000	.000000	.000100
2	11	.000100	.000000	.000000	.000000	.000000	.000100
2	12	.000100	.000000	.000000	.000000	.000000	.000100
2	13	.000400	.001000	.000000	.000000	.000000	.001400
2	14	.000300	.000300	.000000	.000000	.000000	.000600
2	15	.000000	.000100	.000000	.000000	.000000	.000100
2	16	.000100	.000100	.000000	.000000	.000000	.000200
TOTAL		.002200	.005300	.001400	.000300	.000000	.009200

CLASSIFICATION 3A

		WS (m/s)					
ST	WD	0-1.4	1.5-3.4	3.5-5.5	5.6-7.9	≥ 8.0	TOTAL
3	1	.000000	.000000	.000000	.000000	.000000	.000000
3	2	.000000	.000000	.000000	.000000	.000000	.000000
3	3	.000000	.000000	.000000	.000000	.000000	.000000
3	4	.000000	.000000	.000000	.000000	.000000	.000000
3	5	.000000	.000000	.000000	.000000	.000000	.000000
3	6	.000000	.000000	.000000	.000000	.000000	.000000
3	7	.000000	.000000	.000000	.000000	.000000	.000000
3	8	.000000	.000000	.000000	.000000	.000000	.000000
3	9	.000000	.000000	.000000	.000000	.000000	.000000
3	10	.000000	.000000	.000000	.000000	.000000	.000000
3	11	.000000	.000000	.000000	.000000	.000000	.000000
3	12	.000000	.000000	.000000	.000000	.000000	.000000
3	13	.000000	.000000	.000000	.000000	.000000	.000000
3	14	.000000	.000000	.000000	.000000	.000000	.000000
3	15	.000000	.000000	.000000	.000000	.000000	.000000
3	16	.000000	.000000	.000000	.000000	.000000	.000000
TOTAL		.000000	.000000	.000000	.000000	.000000	.000000

CLASSIFICATION 3B

ST	WD	ws (m/s) 0 ~ 1.4	1.5 - 3.4	3.5 - 5.5	5.6 - 7.9	≥ 8.0	TOTAL
3	1	.000000	.000000	.000000	.000000	.000000	.000000
3	2	.000100	.000000	.000000	.000000	.000000	.000100
3	3	.000000	.000000	.000000	.000000	.000000	.000000
3	4	.000100	.000000	.000000	.000000	.000000	.000100
3	5	.000000	.000100	.000000	.000000	.000000	.000100
3	6	.000100	.000000	.000000	.000000	.000000	.000100
3	7	.000000	.000000	.000000	.000000	.000000	.000000
3	8	.000000	.000100	.000000	.000000	.000000	.000100
3	9	.000000	.000100	.000100	.000000	.000000	.000200
3	10	.000000	.000100	.000000	.000000	.000000	.000100
3	11	.000000	.000000	.000000	.000000	.000000	.000000
3	12	.000000	.000000	.000000	.000000	.000000	.000000
3	13	.000000	.000000	.000000	.000000	.000000	.000000
3	14	.000000	.000000	.000000	.000000	.000000	.000000
3	15	.000000	.000000	.000000	.000000	.000000	.000000
3	16	.000000	.000000	.000000	.000000	.000000	.000000
TOTAL		.000300	.000400	.000100	.000000	.000000	.000800

CLASSIFICATION 3C

ST	WD	0 - 1.4	1.5 - 3.4	3.5 - 5.5	5.6 - 7.9	≥ 8.0	TOTAL
3	1	.000000	.000100	.000000	.000000	.000000	.000100
3	2	.000100	.000100	.000000	.000000	.000000	.000200
3	3	.000000	.000100	.000000	.000000	.000000	.000100
3	4	.000100	.000200	.000000	.000000	.000000	.000300
3	5	.000300	.000500	.000000	.000000	.000000	.000800
3	6	.000300	.000400	.000000	.000000	.000000	.000700
3	7	.000500	.000100	.000000	.000000	.000000	.000600
3	8	.000200	.000400	.000000	.000000	.000000	.000600
3	9	.000400	.000600	.000000	.000000	.000000	.001000
3	10	.000800	.000000	.000000	.000000	.000000	.000800
3	11	.000200	.000600	.000000	.000000	.000000	.000800
3	12	.000300	.000400	.000000	.000100	.000000	.000800
3	13	.000500	.000100	.000000	.000000	.000000	.000600
3	14	.000100	.000000	.000000	.000000	.000000	.000100
3	15	.000100	.000100	.000000	.000100	.000000	.000300
3	16	.000000	.000100	.000000	.000000	.000000	.000100
TOTAL		.003900	.003800	.000000	.000200	.000000	.007900

CLASSIFICATION 3D

ST	WD	WS (m/s) 0-1.4	1.5-3.4	3.5-5.5	5.6-7.9	≥8.0	TOTAL
3	1	.000400	.000600	.000200	.000000	.000000	.001200
3	2	.000500	.000400	.000000	.000100	.000000	.001000
3	3	.000500	.001300	.000000	.000000	.000000	.001800
3	4	.001000	.001900	.000000	.000000	.000100	.003000
3	5	.000900	.003000	.000100	.000000	.000000	.004000
3	6	.001200	.004400	.000000	.000000	.000000	.005600
3	7	.002600	.006700	.000200	.000000	.000000	.009500
3	8	.001400	.005700	.000800	.000100	.000000	.008000
3	9	.001400	.005600	.001700	.000200	.000000	.008900
3	10	.001100	.002500	.000300	.000100	.000000	.004000
3	11	.000800	.002400	.000200	.000200	.000000	.003600
3	12	.000400	.001200	.000200	.000100	.000000	.001900
3	13	.000200	.001200	.000000	.000000	.000000	.001400
3	14	.000400	.000100	.000100	.000000	.000000	.000600
3	15	.000200	.000400	.000100	.000000	.000000	.000700
3	16	.000200	.000300	.000000	.000000	.000000	.000500
TOTAL		.013200	.037700	.003900	.000800	.000100	.055700

CLASSIFICATION 3E

ws(m/s)

ST	WD	0-1.4	1.5-3.4	3.5-5.5	5.6-7.9	≥ 8.0	TOTAL
3	1	.000000	.000400	.000400	.000000	.000000	.000800
3	2	.000200	.000600	.000100	.000300	.000000	.001200
3	3	.000300	.002100	.000100	.000100	.000000	.002600
3	4	.000600	.003500	.000200	.000000	.000100	.004400
3	5	.001200	.006100	.000000	.000000	.000500	.007800
3	6	.001400	.007500	.000100	.000200	.000000	.009200
3	7	.002900	.028200	.001800	.000000	.000000	.032900
3	8	.001600	.039300	.040600	.002600	.000000	.084100
3	9	.000600	.023100	.038600	.001600	.000000	.063900
3	10	.000400	.002600	.001400	.000200	.000100	.004700
3	11	.000300	.001300	.001100	.000100	.000000	.002800
3	12	.000300	.000800	.000600	.000000	.000000	.001700
3	13	.000100	.001600	.000800	.000200	.000000	.002700
3	14	.000000	.000900	.000800	.000400	.000200	.002300
3	15	.000000	.000200	.000200	.000000	.000000	.000400
3	16	.000000	.000200	.000100	.000200	.000000	.000500
TOTAL		.009900	.118400	.086900	.005900	.000900	.222000

CLASSIFICATION 3F

ST	WD	WS (m/s) 0-1.4	1.5-3.4	3.5-5.5	5.6-7.9	≥ 8.0	TOTAL
3	1	.000000	.000000	.000000	.000000	.000000	.000000
3	2	.000000	.000000	.000000	.000000	.000000	.000000
3	3	.000000	.000000	.000100	.000000	.000000	.000100
3	4	.000100	.000100	.000000	.000000	.000000	.000200
3	5	.000000	.000000	.000000	.000000	.000000	.000000
3	6	.000000	.000200	.000000	.000000	.000000	.000200
3	7	.000000	.002700	.000400	.000000	.000000	.003100
3	8	.000200	.015000	.039900	.003000	.000000	.058100
3	9	.000000	.004900	.005600	.000200	.000000	.010700
3	10	.000000	.000000	.000000	.000000	.000000	.000000
3	11	.000000	.000000	.000000	.000000	.000000	.000000
3	12	.000000	.000000	.000000	.000000	.000000	.000000
3	13	.000000	.000100	.000000	.000000	.000000	.000100
3	14	.000000	.000000	.000100	.000000	.000000	.000100
3	15	.000000	.000000	.000000	.000000	.000000	.000000
3	16	.000000	.000100	.000000	.000000	.000000	.000100
TOTAL		.000300	.023100	.046100	.003200	.000000	.072700